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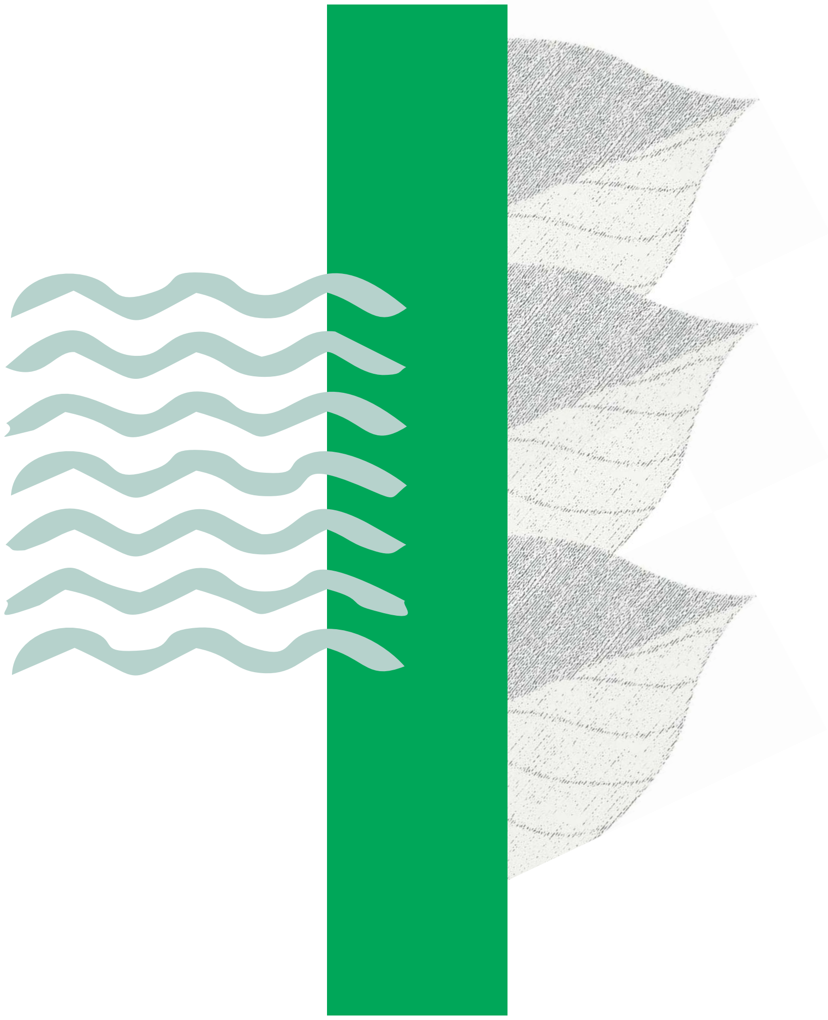

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Editorial

SCIENTIFIC PUBLICATIONS OF THE BalticSTE INTERNATIONAL SYMPOSIA: TRENDS AND SHIFTS IN SCIENCE AND TECHNOLOGY EDUCATION THEMES (2015–2023)

Vincentas Lamanauskas
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BalticSTE (Baltic Science and Technology Education) is an international scientific event dedicated to the issues of *Science & Technology Education* (STE) in the Baltic states and beyond. The first international symposium took place in 2015. It can be reasonably said that the ideological platform of this symposium was the national scientific practical conference "Science education in general education school", organised every year since 1995. Five international symposia took place from 2015 to 2023. It is obvious that these symposia brought together researchers, scientists, educators, policymakers, and other persons interested in science and education technology from various countries and institutions.

Natural Science and Technology Education (NSTE) promotes critical thinking, creativity, and problem-solving skills that are necessary for the 21st century job market. Productive discussions about best practices and the latest technologies help modernise education and adapt it to the rapidly changing world reality. BalticSTE symposia provide opportunities for the Baltic countries and foreign partners to exchange experiences, design joint educational solutions, and strengthen the scientific potential of the region.

In recent years, both in Lithuania and in other countries, much attention has been paid to the development of natural sciences and technologies. The declining interest of young people in natural sciences and/or technologies is of great concern (Lamanauskas, 2015). Thus, one of the main goals is to strengthen natural sciences and technology education. It must be said that the state of NSTE in Lithuania in the period from 2015 to 2025 experienced significant changes related to the improvement of educational policy, infrastructure, and teaching methods. Undoubtedly, during this period, this area has improved significantly, both in terms of infrastructure and methodology. Although natural sciences education in Lithuania has made significant progress over the past 10 years (technologies, international projects, STEM centres), structural problems remain (shortage of natural sciences teachers, low student motivation, etc.).

So, as already mentioned, five international BalticSTE symposia took place. During them, a lot of scientific, methodological, practical reports of various kinds were made, practical work and seminars were organised. Of course, scientific articles were published. A total of 150 articles were published (Table 1).

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Table 1
BalticSTE Symposium Publications

Year	Number of publications	Number of countries	Number of authors
2015	33	12	68
2017	34	16	65
2019	44	21	93
2021	16	13	27
2023	23	13	43

All publications are open access; they can be found on the symposium website, as well as in the databases CEEOL, ERIC, Scribd, DOI, Crossref, Internet Archive, Google Scholar, etc.

An analysis of the published articles was carried out according to the most important thematic areas. In total, the articles are divided into seven thematic/subject areas. Although this division is partly conditional, certain trends can be discerned (Table 2).

Table 2
Distribution of Published Symposium Articles by Thematic Areas [N (%)]

Area / Subject	2015	2017	2019	2021	2023	Total
Chemistry Education	10	8	8	3	6	35 (23.3)
Physics Education	2	5	6	3	2	18 (12)
Biology Education	0	3	3	1	1	8 (5.3)
Ecology and Environmental Education	0	4	2	0	4	10 (6.7)
Educational Technology	7	2	7	3	3	22 (14.7)
STEM Education	0	0	2	2	0	4 (2.6)
General articles	14	12	16	4	7	53 (35.4)
Total	33	34	44	16	23	150 (100.0)

As can be seen in Table 2, the largest proportion of articles was of a general nature (35.4%), in which common natural sciences and technology education topics, trends, and methodological questions were analysed. The second largest group of articles was devoted to chemistry education (23.3%). This shows that a significant portion of scientific research is devoted to the issues of chemistry education. Articles on educational technologies account for 14.7%, reflecting the growing integration of technologies into the learning process. Articles on physics education account for 12%, biology – 5.3%, ecology and environmental protection – 6.7%. The least attention was paid to STEM (integrated science, technology, engineering and mathematics education) (2.6%). This may indicate a less developed direction of research on STEM topics or the need for its integration in the future.

General trends show that most attention is paid to general issues of natural science and technology education, but there is also a clear orientation towards specific disciplines (especially chemistry), as well as towards the growing role of technology in the educational process.

After analysing the presented list of 150 symposium articles, it is possible to distinguish several main thematic directions and their change from 2015 to 2023. Of course, such a division is rather conditional, but in any case, it allows us to discern certain aspects of thematic changes. When it comes to publications in 2015,

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it can be seen (Lamanauskas et al., 2015) that attention is focused on general topics of natural science and technology education, such as the effectiveness of educational methods, educational competencies, students' interest in natural sciences and mathematics. The issues of chemistry teaching are relatively actively analysed, emphasising educational strategies (e.g., critical thinking, interdisciplinary integration, etc.). It can also be argued that the use of educational technologies is expressed as an important trend, with a relatively large number of articles on the application of information communication technologies in the classroom.

There are 34 articles published in the 2017 symposium publication (Lamanauskas, 2017). It can be noted that there is a stronger focus on interdisciplinary topics and environmental education. Undoubtedly, a more intensive analysis of physics teaching and ecological education topics is noted. Teacher professional development and the application of active learning strategies (for example, inquiry-based learning (IBSE), problem solving, conscious learning) have become much more significant topics (research areas).

The largest number of articles, as many as 44, were published in the publication of the fourth symposium held in 2019 (Lamanauskas, 2019). It is undoubtedly noticeable that the attention to educational technologies and digital tools in the educational process has increased significantly. Student assessment and self-assessment strategies, as well as formal assessment, have become much more prominent. The integration of the STEM direction is clearly noticeable, although there are few articles, but for the first time, it clearly stands out as a separate area. It should be noted that there is a clearer focus on teachers' pedagogical knowledge and competencies, especially in the context of physics and chemistry teacher training.

In 2021, the symposium was held remotely (Lamanauskas, 2021). This situation arose due to the prevailing COVID-19 pandemic. This is also reflected in the number of articles prepared for publication. Only 16 were published that year. Despite the noticeably smaller number of articles (possibly due to the influence of the pandemic), there is a clear focus on the teacher and students' ability development, taking into account the 21st century competencies. Particular emphasis is placed on digital education, digital competencies, distance and integrated teaching/learning. Students' cognitive abilities and the development of scientific thinking have begun to be assessed and analysed more.

The fifth international BalticSTE2023 symposium took place after the pandemic period, in 2023. (Lamanauskas, 2023). Analysing the published articles, it can be seen that the integration of modern technologies is emphasised (e.g., 3D holograms, chatbots, IoT (Internet of Things), interactive content, etc.). The topics of the publications (and, of course, the research conducted) are clearly oriented towards developing practical skills, solving ecological issues, and raising public awareness (e.g., biodegradability, environment preservation, etc.). There is also a greater focus on inclusive education, teaching students with special needs, and teaching differentiation.

It is not very reliable to talk about certain trends or directions of this period on the basis of publications, but some directions can be discerned. One could probably talk about certain insights, observations, rather than very clear directions. However, this helps to understand the general problematic of educational research in the field of NSTE more clearly. For example, by reviewing the publications from 2015 to 2023, the direction of technological breakthroughs and digitalisation is observed. If in 2015 there were only individual publications on educational technologies, then later it became practically one of the most important research directions. One cannot fail to notice a rather clear trend – this is technology integration into education, starting from simple computer programs and moving on to complex interactive technologies, such as 3D holograms, IoT, virtual or augmented reality tools. Also, increasing attention is paid to interdisciplinary interfaces (especially chemistry and mathematics, chemistry and biology), the development of problem-solving skills, and integrated STEM / STEAM directions. As researchers rightly note, it is increasingly recognised that STEM knowledge is a priority in the development of education (Cedere et al., 2020). In addition, access to STEM enables students to become more creative thinkers and problem solvers, with the necessary abilities and skills to solve everyday problems and issues in new and innovative ways (Siew, 2017). Another noticeable direction is ecology and sustainable development. Growing attention to ecological education and environmental awareness is observed especially in works published in 2017 and 2023.

Another noticeable direction is associated with the development of students' cognition and competence. Intensive attention is paid to the development of students' cognitive abilities (metacognition, scientific thinking, research skills, etc.). The need to develop 21st-century skills (critical thinking, creativity, the ability to solve

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complex problems, etc.) is particularly evident. For example, research results show that students with higher cognitive needs often have better academic performance and greater willingness to engage in cognitively demanding activities (Popoviciu et al., 2011).

Another significant trend is also noticeable, which is associated with the evolution of educational methods and techniques. It can be conditionally stated that there is a transition from conventional educational methods to research-based, interactive, problem-based teaching and formative assessment methodologies. In turn, the development of teachers' pedagogical knowledge and competencies is becoming an integral part of scientific and practical research. Researchers note that the goal of teacher education is to prepare a teacher able to master teaching innovations and acquire professionally valuable competencies (Kobalia & Garakanidze, 2010). Promoting an independent learning environment, using everyday contexts and situations, raising challenges for students through open activities, and promoting epistemic practices (e.g., focusing attention, describing, communicating, and reasoning) are significant teacher competencies (Pinto et al., 2014).

After analysing the scientific publications of the 2015–2023 BalticSTE international symposia, it can be stated that the change in the topics of natural science and technological education reflects both global trends in educational development and specific regional needs and challenges. Several important directions have noticeably emerged: the strengthening role of technologies and digitalisation in education, increasing attention to an interdisciplinary and integrated STEM approach, the application of active and innovative teaching methods, and a significant emphasis on ecological and sustainable development. In addition, there is a growing attention to the teachers' professional development, strengthening of their pedagogical competencies, especially focusing on the ability to apply modern technologies, and interactive teaching (learning) strategies. Although the division of thematic areas is partly conditional, it allows us to clearly see the trends and changes over the past years. A clear necessity is seen to further develop STEM education, promote students' motivation and interest in natural sciences and technologies, and strengthen students' skills, necessary in the 21st century. BalticSTE international symposia, held from 2015 to 2023, are undoubtedly an important platform for scientific research and discussions on natural science and technology education.

References

Cedere, D., Birzina, R., Pigozne, T., & Vasilevskaya, E. (2020). Perceptions of today's young generation about meaningful learning of STEM. *Problems of Education in the 21st Century*, *78*(6), 920–932. https://doi.org/10.33225/pec/20.78.920

Kobalia, K., & Garakanidze, E. (2010). The professional competencies of the 21st century school teacher. *Problems of Education in the 21st Century*, *20*(1), 104–108. https://www.scientiasocialis.lt/pec/node/376

Lamanauskas, V. (2015). Gamtamokslinis ir technologinis ugdymas: vertybių svarba [Natural science and technology education: Importance of values]. *Gamtamokslinis ugdymas / Natural Science Education*, *12*(3), 124–126. https://doi.org/10.48127/gu-nse/15.12.124

Lamanauskas, V. (Ed.) (2017). *Science and technology education: Engaging the new generation. Proceedings of the 2nd International Baltic Symposium on Science and Technology Education (BalticSTE2017)* (144 p.). Scientia Socialis Press. https://www.ceeol.com/search/book-detail?id=941411

Lamanauskas, V. (Ed.). (2019). *Science and technology education: Current challenges and possible solutions. Proceedings of the 3rd International Baltic Symposium on Science and Technology Education (BalticSTE2019)*. Scientia Socialis Press. https://www.ceeol.com/search/book-detail?id=942413

Lamanauskas, V. (Ed.). (2021). *Science and technology education: Developing a global perspective. Proceedings of the 4th International Baltic Symposium on Science and Technology Education (BalticSTE2021)*. Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2021.95

Lamanauskas, V. (Ed.). (2023). *Science and technology education: New developments and innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)*. Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.122

Lamanauskas, V., Šlekienė, V., & Ragulienė, L. (Eds.). (2015). *State-of-the-art and future perspectives: Proceedings of the 1st International Baltic Symposium on Science and Technology Education (BalticSTE2015)*. Scientia Socialis Press. https://www.ceeol.com/search/book-detail?id=940820

Pinto, A. J., Lopes, B. J., Silva, A. A., & Santos, C. A. (2014). Developing a teacher education program to promote scientific literacy and improve a positive attitude about science. *Problems of Education in the 21st Century*, *60*(1), 134–155. https://dx.doi.org/10.33225/pec/14.60.134

Popoviciu, S. A., Barbu, A., Costea, D., Culda, L., & Culda, S. (2011). Students' desire to engage in cognitive activities, family of origin characteristics and need for cognition scores. *Problems of Education in the 21st Century*, *33*(1), 62–72. https://dx.doi.org/10.33225/pec/11.33.62

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Siew, N. M. (2017). Fostering students' scientific imagination in STEM through an engineering design process. *Problems of Education in the 21st Century*, *75*(4), 375–393. https://doi.org/10.33225/pec/17.75.375

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UNCOVERING UNDERGRADUATE PHYSICS PRE-SERVICE TEACHERS' ERRORS IN ELECTROMAGNETIC INTERACTION AND ELECTROMAGNETIC EFFECTS

Sakyiwaa Boateng,
Sizwe J.C. Masuku

Abstract. *Electricity and magnetism are fundamental areas of physics and are integral to science curricula at various educational levels. However, this area has been reported to contain several concepts that students find challenging, leading to perspectives that diverge from scientifically accepted views. This study examines the errors made by physics pre-service teachers (PPSTs) in electromagnetic interaction and electromagnetic effects, using the De Jong and Ferguson-Hessler framework of knowledge types to classify errors into conceptual, procedural, and situational categories. An interpretivist qualitative case study design was employed. The study was conducted with a class of 86 third-year undergraduate PPSTs enrolled in a physical sciences education program. Data were collected using a test designed to assess PPSTs' understanding of key electromagnetic concepts. The test results revealed recurring errors in conceptual understanding and problem-solving techniques, particularly in interpreting electric and magnetic fields, Coulomb's law, and applying Maxwell's equations. Findings suggest that targeted educational interventions focusing on improving students' conceptual and procedural knowledge, along with strategic approaches to problem-solving, could reduce the frequency of these errors. Hence, this study highlights the need for more focused teacher training to address these difficulties related to electricity and magnetism and its long-term impact on physics education.*

Keywords: *conceptual errors, electromagnetic interaction, physics pre-service teachers, procedural errors, physics education*

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Introduction

Conceptual understanding is a crucial objective in education, particularly in science education, as it is essential for grasping phenomena. It entails the construction of meaning, interpretation, and elucidation (Anderson et al., 2001). It entails mastery of the principles that regulate a domain and the interconnections among pieces of knowledge within that domain (Rittle-Johnson et al., 2001). In contrast to conceptual understanding, conceptual misunderstanding encompasses notions that are "incorrect and deficient" (Gurel et a., 2015) and are at odds with scientific knowledge or assertions. These notions may be called alternate conceptions, misconceptions, preconceptions, alternative frameworks or naive ideas (Coştu, et al., 2011). Misunderstandings and misconceptions can be enduring (Sangam & Jesiek, 2012), obstruct learning (Ebenezer et al., 2009), and resist transformation (Turgut et al., 2011) of knowledge, particularly in science education.

In science education, physics is universally recognised as a demanding discipline for both learners and teachers (Çermik, 2020; Liu & Sun, 2021). Electricity and magnetism are important topics in physics that require prior knowledge in mathematics. Electromagnetism is a core component of the undergraduate physics curriculum, typically introduced through sub-units in electricity and magnetism. The sub-units covered include Coulomb's law, electric fields, magnetic fields, Faraday's law of induction, Gauss law and Maxwell's equations. (Griffiths, 2017). These concepts underpin numerous technological advancements and applications, from everyday electronic devices to advanced scientific instrumentation. Enhancing student conceptual understanding and problem-solving skills is a primary objective in courses for physics majors and graduate students, despite using complex mathematics to address problems (Bollen et al., 2018). Mastery of these concepts is essential by assisting students in integrating conceptual and quantitative dimensions of learning to establish a solid knowledge framework of fundamental principles in electricity and magnetism for academic success and practical applications in various fields such as electrical engineering, telecommunications, and medical imaging (Maries et al., 2022). Understanding these laws helps students appreciate the practical implications of electromagnetic theory in

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real-world applications, such as energy generation and transmission (Qin, 2023). Understanding electromagnetic interactions and their resulting effects is fundamental to studying physics and engineering (Alihodžić, et al., 2021).

Despite their importance, students often struggle with mastering these topics, leading to significant errors in comprehension and application (Guisasola, 2014). Research on students' comprehension of electric and magnetic fields at both secondary and undergraduate levels indicates prevalent confusion and alternative conceptions regarding fields and forces, which begin in high school and continue into university (Boateng & Mushayikwa, 2022; Guisasola, 2014; Hoyer & Girwidz, 2024; Zuza et al., 2018). Students encounter challenges in connecting phenomenology, such as observable electromagnetic interactions, with the theoretical frameworks that elucidate these observable changes in terms of fields (Zuza et al., 2018).

Researchers have noted that students equate fields with forces while elucidating unknown electric and magnetic phenomena (Furió & Guisasola, 1998). Many studies have explored students' conceptual difficulties in understanding Gauss's and Ampère's laws, as well as related concepts such as electric flux and magnetic circulation. Common challenges in both contexts encompass the confusion between electric field and flux (Guisasola et al., 2008; Li & Singh, 2018a; Pepper et al., 2012), magnetic field and circulation (Bozzo et al., 2022; Guisasola et al., 2010), the erroneous application of the principle of superposition by presuming that only enclosed field sources produce a field (Guisasola et al., 2008; Li & Singh, 2018b; Pepper et al., 2012), and the inability to identify the requisite symmetry conditions for employing Gauss or Ampere's law to calculate the electric or magnetic field (Li & Singh, 2018b; Wallace & Chasteen, 2010).

Related studies have also shown that students have misconceptions and often make errors ranging from fundamental misunderstandings of vector fields and forces to incorrect applications of mathematical principles (Assem et al., 2024; Mbonyiryivuze et al., 2019). These misconceptions and errors can be attributed to several factors, including the abstract nature of the concepts, the mathematical rigour required, and the often counter-intuitive phenomena described by electromagnetic theory. The concepts' abstractness further compounds the difficulty in understanding electricity and magnetism. Garduza et al. (2023) have pointed out that students often struggle to connect theoretical knowledge with practical applications, particularly in electrostatics, where the relationships between electric fields, forces, and potentials have not been intuitively grasped. This disconnect is echoed by Rahmawati et al. (2023), who have identified the abstract nature of electrical concepts as a significant barrier to student understanding. Hence, the challenge lies in bridging the gap between theoretical constructs and tangible experiences, which is essential for fostering a comprehensive understanding of these topics. For instance, research by Bollen et al. (2016) highlighted that while students could perform calculations, they struggled with the structural understanding of vector operators and applying Maxwell's equations correctly. Similarly, Zuza et al. (2018) found that students faced difficulties linking observable electromagnetic interactions to theoretical explanations, indicating a gap in understanding the underlying principles. These studies collectively underline the importance of identifying and addressing misconceptions and errors in electromagnetism to enhance undergraduate education.

A convergence of these studies indicates that many students do not understand electromagnetism well (Boateng & Mushayikwa, 2022; Bollen et al., 2016; Garduza et al, 2023; Zuza et al., 2018). Most research on students' difficulties with electromagnetism primarily focuses on tertiary-level students and examines more advanced concepts (Hernandez et al., 2023; Suarez et al., 2024). While many studies address general misconceptions in physics, there is a gap in research focusing specifically on physics pre-service teachers (PPST) errors in learning detailed subtopics within electromagnetic interactions and effects, such as Maxwell's equations, Faraday's law, or the nature of electric and magnetic fields in various contexts (e.g., time-varying fields). In addition, research has often generalized student errors across different areas of electricity and magnetism without considering how different contexts (e.g., conceptual vs. problem-solving approaches) influence error patterns. Studies exploring how specific contexts affect error rates are lacking. Hence, there is a need to explore PPST errors and misconceptions at the undergraduate level to understand the errors made by PPSTs in electromagnetic interaction and electromagnetic effects to devise strategies to enhance their learning outcomes in physics education.

Theoretical Framework

Conceptualising Conceptual and Procedural Knowledge in Electricity and Magnetism

In physics education, conceptual knowledge refers to the understanding of fundamental physics principles and the ability to identify and define relevant concepts (Vuola & Nousiainen, 2020). On the other hand, procedural

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knowledge involves the methodological dimension of knowledge, including the procedural nature of experiments and model development necessary to connect physics concepts and laws (Nousiainen, 2012). Research suggests that conceptual and procedural knowledge in physics is interconnected and develops iteratively (Rittle-Johnson et al., 2001). While conceptual knowledge influences procedural knowledge, the reverse relationship is also observed, indicating a bidirectional influence between the two (Rittle-Johnson & Alibali, 1999). This iterative process of development is facilitated by improved problem representation, which aids in bridging the gap between conceptual understanding and procedural skill (Rittle-Johnson et al., 2001). Moreover, the retention of conceptual learning in physics is essential, as demonstrated in studies evaluating students' understanding following interactive physics courses (Wilcox et al., 2020). Active engagement in physics courses, coupled with a focus on conceptual understanding, contributes to long-term knowledge retention. In teaching physics, emphasising conceptual knowledge over mathematical knowledge is recommended to enhance students' understanding (Aprianti, 2023). By focusing on conceptual understanding, teachers can support students in developing deep knowledge of physical phenomena (Carpendale & Cooper, 2021).

Situational knowledge denotes understanding prevalent problem scenarios or contexts within a specific domain, aiding a solver in identifying critical features and articulating the problem effectively. Visualisation construction and other representational methods that support the problem statement effectively reflect situational knowledge (Shavelson et al., 2003).

This study categorises and examines students' conceptual, procedural, and situational knowledge based on the framework proposed by De Jong and Ferguson-Hessler (1996). According to De Jong and Ferguson-Hessler (1996), the quality of knowledge can be evaluated according to its depth, organisation, and interrelations among various knowledge components. High-quality knowledge is distinguished by a coherent structure, facilitating enhanced retrieval and application in problem-solving contexts. In contrast, low-quality information can be disjointed or cursory, resulting in challenges in its application and adaptation to new situations (Fauskanger & Bjuland, 2018). This distinction is crucial in educational contexts, where the objective is to amass information and cultivate a profound comprehension that can be utilised in practical scenarios. The framework's significance transcends theoretical discourse and has practical ramifications for curriculum development and teaching methodologies. Teachers are urged to cultivate learning settings that promote the advancement of all three categories of knowledge. This can be accomplished using diverse instructional methods, such as problem-based learning, which challenges students to confront real-world issues necessitating the amalgamation of conceptual, procedural, and conditional knowledge as suggested by Bruns et al. (2021).

Literature Review

Students' Common Errors and Misconceptions in Electricity and Magnetism Concepts

Misconceptions, also called common errors, are incorrect understandings or flawed interpretations of concepts, often deeply rooted in learners' cognitive frameworks (Smith et al., 1994). In physics education, misconceptions are particularly significant as they tend to be robust and resistant to change, even after teaching (Chi, 2005; Disessa, 1988). Misconceptions in physics are often formed from everyday experiences or prior knowledge that conflicts with scientific principles (Hammer, 1996). Chi (2013) has described misconceptions as alternative frameworks that learners construct, often influenced by their pre-existing mental models. In electromagnetism, for example, students might incorrectly assume that electric current flows as if it is water, which is flowing in pipes, or electric and magnetic fields are similar to tangible physical objects.

According to Duit (2014), misconceptions in physics can be classified into several categories: preconceptions (ideas formed before formal instruction), flawed mental models (simplified or incorrect internal representations of phenomena), and intuitive reasoning errors (incorrect extrapolations from everyday experiences). These misconceptions tend to persist because they provide students with seemingly logical explanations for observed phenomena, even if those explanations conflict with scientific principles.

Nevertheless, a conceptual error refers to a misunderstanding of a concept that does not align with the scientific definition commonly accepted by experts in the relevant field. One standard conceptual error relates to understanding electromagnetic fields and their effects. Students may incorrectly interpret the behaviour of electromagnetic field lines, leading to misconceptions about the direction and magnitude of forces exerted by these fields (Dori & Belcher, 2005). Moreover, misconceptions about the nature of electromagnetic fields in matter compared to vacuum can complicate students' visualization and comprehension of electromagnetic interactions

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(Choi & Yun, 2019). A lack of comprehension of the problem's concepts or a misunderstanding of the link between the problem's concepts are both examples of conceptual mistakes. For example, pre-service teachers misinterpreting Gauss's Law for electric fields (which relates the electric flux through a closed surface to the charge enclosed) can cause errors in calculating electric fields for various charge distributions.

A procedural error refers to errors in the process of executing algorithmic procedures, which include operations, algorithms, placements, and incorrect steps, as well as missing steps in problem-solving (Herholdt & Sapire, 2014; Siyepu, 2013). Procedural error may be due to mis-generalisation, where students generalise an existing concept wrongly (Andriani & Nurhasanah, 2021). Furthermore, procedural errors occur when students correctly understand the fundamental concepts and theories but make mistakes in applying them to solve problems. One possible source of procedural errors in electromagnetism is the misapplication of fundamental concepts such as electric and magnetic fields, charges, and currents. For instance, calculating electromagnetic forces or fields could lead to inaccuracies in predicting the behaviour of charged particles or magnetic materials.

Several studies have documented common errors in students' understanding of electromagnetic concepts (Lattery, 2016; Leniz et al., 2017; Maloney et al., 2021). For instance, Lattery (2016) identified common errors in Faraday's Law and Lenz's Law, where students often believe that a change in magnetic flux directly creates current without recognizing the induced electric field. Duit and Treagust (2012) also highlighted that students frequently misinterpret induced current direction, assuming it flows in the same direction as the external magnetic field instead of opposing the change in flux. Similarly, Maloney et al. (2021) noted that students frequently confuse the concepts of electric potential and electric field, incorrectly assuming they are the same or have identical effects on charged particles. This stems from an inappropriate analogy and a misunderstanding of charge conservation in electric circuits, as Leniz et al. (2017) noted in their study. A frequent error involves conflating electric potential with electric field strength, leading students to assume incorrectly that the two are directly proportional, regardless of the spatial configuration of the charges. Students often confuse electric potential with electric field strength, resulting in misunderstandings regarding their interaction in a circuit. Studies reveal that students frequently do not comprehend that electric potential is a scalar variable affecting charge flow in an electric field, as Leniz et al. (2017) noted.

In magnetism, students often possess incorrect notions about magnetic fields and forces. One common misconception is that magnetic field lines represent physical entities that can be "seen" or that their density directly indicates magnetic strength. Moreover, students struggle to understand that magnetic forces act at a distance, leading to incorrect interpretations of how magnetic fields interact with moving charges or currents. A study by Maloney et al. (2021) shows that many university students incorrectly believe that a magnetic field can exert force on a stationary charged particle. This misconception arises from confusion between electric and magnetic forces, with students failing to recognize that the magnetic force acts only on moving charges. These conceptual errors are compounded when students try to apply the right-hand rule, often confusing the direction of the magnetic force and current flow (Heckler & Sayre, 2010).

Electromagnetic interactions present an additional layer of complexity, as students must integrate their understanding of both electric and magnetic fields. Many students mistakenly believe that a magnetic field alone can induce current without changing the magnetic flux (Mulhall et al., 2001). Maloney (1985) conducted a study assessing students' understanding of magnetic poles following instruction in a general physics course. The findings indicated that most students held an alternative conception, believing that magnetic poles are charged, which indicates a significant issue is students' challenges in visualising electric and magnetic fields. In a similar study, Malgieri et al. (2021) found that students often struggle to accurately draw field lines for magnets, indicating a fundamental misunderstanding of how magnetic fields operate. This difficulty is echoed by Gülçiçek and Damlı (2018), who highlight that students' representations of magnetism as magnetic poles or field lines can lead to confusion when solving problems related to force. The inability to visualize these concepts can significantly impede students' problem-solving abilities in electricity and magnetism.

The question is, how do we prepare pre-service teachers to teach physics effectively and with understanding? Studies have shown that inquiry-based learning encourages students to engage actively with scientific concepts through questioning, investigation, and problem-solving (Listiono et al., 2025; Safkolam et al., 2024; Sapriati et al., 2024). Sapriati et al (2024) emphasised that inquiry has become synonymous with effective science learning, particularly biology. This suggests that teacher education programs must integrate inquiry skills into their curricula to foster a deeper understanding of scientific principles among pre-service teachers. Experiential learning (Ng et al.,.2019; Pherson-Geyser et al., 2020), which emphasizes learning through experience and reflection, is another effective pedagogical approach for preparing pre-service teachers in physics. This method allows pre-service

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teachers to engage in hands-on activities that mirror real-world scientific practices. This suggests that experiential learning opportunities should be a core component of teacher education programs, enabling pre-service teachers to develop practical skills in teaching physics.

Research Aim and Research Questions

This study examines PPSTs' common errors in understanding and applying physics concepts during problem-solving.

The following research questions guided the study:

1. What are the common cognitive errors and misconceptions PPSTs exhibit in understanding electromagnetic interactions and effects, as identified through science knowledge classification analysis?
2. What specific stages of science knowledge classification (situational, conceptual, procedural) do PPSTs struggle with the most when learning about electromagnetic interactions and effects, and what are the contributing factors?

Research Methodology

General Background

This study adopts an interpretivist qualitative case study approach to uncover and understand third-year PPSTs' errors in electromagnetic interactions and their effects. The interpretivist paradigm is suitable for this research as it aims to explore students' subjective experiences and conceptual understanding, recognizing that knowledge is constructed through social and individual interpretation (Creswell, 2013). The case study design (Yin, 2018) was employed to facilitate a comprehensive dataset that encapsulates diverse experiences and insights inside a singular educational environment. Yin (2018) has highlighted the significance of context in case study research, especially pertinent when analysing the learning environment of these PPSTs. This implies that the study deeply explores how the specific learning environment, instructional methods, and prior knowledge shape PPSTs' misconceptions and problem-solving approaches. A case study allows for an in-depth, situated understanding of these errors, considering real classroom interactions, assessment practices, and educational interventions. This approach helps develop targeted strategies to address conceptual and procedural difficulties, ultimately improving teacher preparation and physics education quality.

Sample

The participants included a whole third-year physics class of 86 PPSTs registered for the Physics III course in a 4-year Bachelor of Education degree programme in a university in the Eastern Cape region of South Africa. The study employed a whole-class sampling approach, meaning all 86 PPSTs in the cohort participated (47 males, 55%; 39 females, 45%). This decision was made to ensure inclusivity and representativeness within the course. While the study provides meaningful insights into the targeted group of PPSTs, generalizability beyond this cohort could be considered within the context of similar teacher education programs, as the study aims for transferability, where insights can inform broader discussions in teacher education. No formal sample size calculation was necessary since the study involved the entire available cohort. The decision to include all students was based on accessibility and the practical advantage of working with a whole group rather than a subset.

The average age of the participants was 21 years. All participants majored in physics and chemistry as their primary subjects. Mathematics was their third major subject. For anonymity, the participants were randomly coded as PPST1, PPST2, and so on up to PPST86. Before data collection, ethical approval for the study was obtained from the Faculty of Education Ethics Research Committee (with protocol number FEDSRECC014-03-23). Participation was voluntary, and informed consent was secured from all participants. Confidentiality and anonymity were maintained by de-identifying responses and ensuring no participant could be linked to specific data. In addition, participants were informed of their right to withdraw from the study at any stage without any consequences.

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The Physics Course Design for a 4-Year B.Ed. Education Programme

The Physics course in this study context was designed to equip pre-service teachers with advanced content knowledge in Physics, enabling them to teach and inspire future learners effectively. The program builds a strong foundation in classical and modern physics, progressing through theoretical and applied aspects to develop deep conceptual understanding and practical teaching strategies.

The first-year Physics I course introduces fundamental concepts in classical and modern physics, emphasizing conceptual clarity and foundational problem-solving skills on the following topics: Classical Mechanics, General Optics, Electricity and magnetism, Current Electricity, Atoms and Kinetic Theory, The Quantum Atomic Theory.

The second-year Physics II course extends the foundational knowledge into more complex topics, covering multi-dimensional motion and quantum aspects of light (Classical Mechanics 2, Thermodynamics, Gas Laws, The Quantum Theory of Light, Modern Physics, Nuclear Physics, The Particle Nature of Photons).

The third-year Physics III course delves into advanced theoretical physics, solid-state, and electromagnetism, preparing students for research and innovative teaching methods (Quantum Mechanics, Statistical Mechanics, Solid State Physics, Modern Physics, Electromagnetism).

The fourth year focuses on practical teaching experience, curriculum development, and research in physics education. This structured curriculum allows pre-service teachers to gain content mastery and develop effective pedagogical approaches to teaching Physics in secondary education, ensuring that pre-service teachers graduate as well-rounded physics teachers capable of teaching, innovating, and researching physics education.

The mode of delivery for this course is a blended learning approach, combining face-to-face lectures, laboratory practicals, interactive tutorials, and digital learning tools to enhance conceptual understanding, using the ideas as framed by Novotná and Demkanin (2024), on the typology of teachers to categorise their approaches and perspectives on teaching physics. By developing this typology, the framework provides insights into variations in teaching styles, instructional decision-making, and how educators address students' learning challenges.

Instrument and Procedures

The study was undertaken in one unit of Physics III (Electricity and Magnetism) following the completion of the unit. The justification for choosing Electricity and Magnetism was that, the unit is a conceptually demanding topic in physics education, often associated with high cognitive load and abstract reasoning. Investigating its impact on preservice teachers' understanding provided valuable insights into their learning processes.

A unit test was administered to the PPSTs, conducted as a supervised test lasting two hours. Conducting the study after the completion of the unit ensured that participants had full exposure to the content and instructional approach before their learning experiences were assessed. This allowed for a more comprehensive evaluation of their conceptual understanding. Data collection after unit completion allowed PPSTs to reflect holistically on their learning experiences and any conceptual challenges they faced. Capturing these reflections, post-instruction provided richer qualitative and quantitative data.

A marking rubric was created and overseen by a subject matter expert, and it was utilized to grade the test. Once the test was scored, the study team assessed each PPST response. A second marker was used to mark the scripts to ensure consistency. A level of agreement of over 95% was attained between the two markers. After finishing the marking process, the PPSTs' responses to the unit test were analysed.

Multiple measures were taken to ensure the validity and reliability of the unit test. Content validity was established by aligning the test items with the learning objectives and key concepts covered in the unit. This ensured that questions adequately represented theoretical and practical aspects of electricity and magnetism. Construct validity was verified through expert reviews by physics specialists, who confirmed that the test accurately measured conceptual understanding and problem-solving skills. The test underwent a pilot study with a small group of PPSTs to enhance reliability to identify ambiguous questions and refine item clarity. Inter-rater reliability was maintained using a standardized rubric for scoring. These measures collectively ensured that the test produced stable and accurate assessments of the PPSTs' understanding of electricity and magnetism.

Data Analysis

In analysing the responses, the researchers did not employ scale scores to assess each PPST's knowledge level. The process of problem analysis required significantly more effort than grading itself. This was because the

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researchers were not concerned with simply determining whether the quantitative solutions were right or wrong. Instead, the researchers focused on identifying the specific errors made by PPSTs and characterizing them to gain insights into their potential learning difficulties when they learn electricity and magnetism.

The researchers employed the framework established by Miles and Huberman (1994) for analysis. This methodology consists of three sequential phases: data reduction, data display, and conclusion drawing and verification. In the data reduction phase, the written responses of each PPST to each question were analysed, and the correct and incorrect responses (errors) were classified using De Jong and Fergusson-Hessler›s (1996) framework of knowledge kinds.

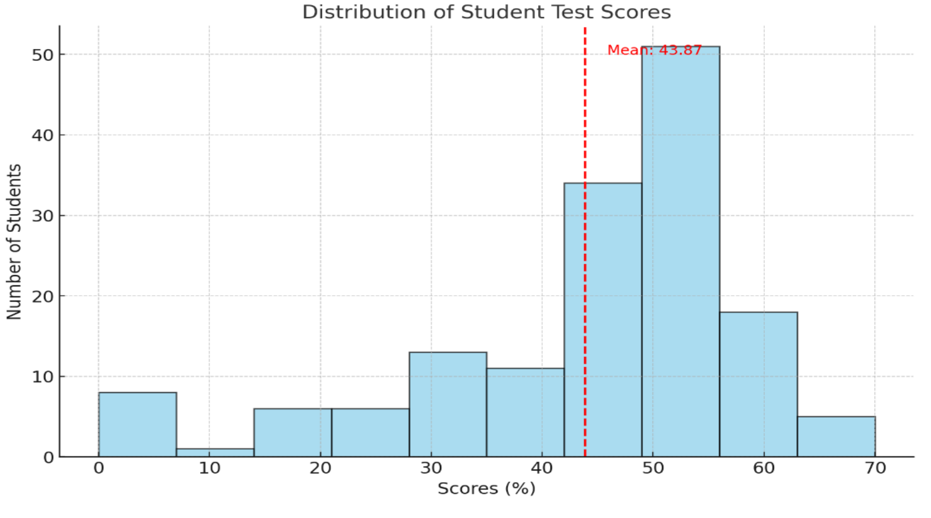
Situational, conceptual, and procedural errors were employed to correlate to the distinct types of knowledge in order to categorize students' errors. Using the analysis and classification method, the researchers classified and documented all errors associated with each test question on a spreadsheet. These errors were subsequently consolidated into a comprehensive test analysis report. This approach ensures a robust analysis of the PPSTs' errors.

Research Results

PPSTs Distribution of Test Scores

The maximum total score for the test was 50 marks (100%), with each item assigned five marks. The analysis indicated that PPSTs' marks varied from 0 marks (0%) to 35 marks (70%), with 0% representing the minimum and 70% the maximum score. The mean score was approximately 43.87, with a standard deviation of 15.32. The distribution of PPST test results, as illustrated in Figure 1, reveals significant variability, highlighting that while some PPSTs performed well, a considerable number fell into lower performance categories.

Figure 1
Distribution of PPSTs Test Scores



Errors in Determining Electrostatics Force Acting on an Expanded Segment

In question 1.1.1, PPSTs had to determine the electrostatic force acting on an expanded segment of a rod aligned along the *z*-axis, with the point of thermal expansion initiation at the origin. The scenario was that a positive charge magnitude +Q was located along the *y*-axis, positioned 1 meter away from the rod. About 90% of PPSTs answered this question wrongly. Figures 2 (a) and (b) show typical PPSTs responses to these questions.

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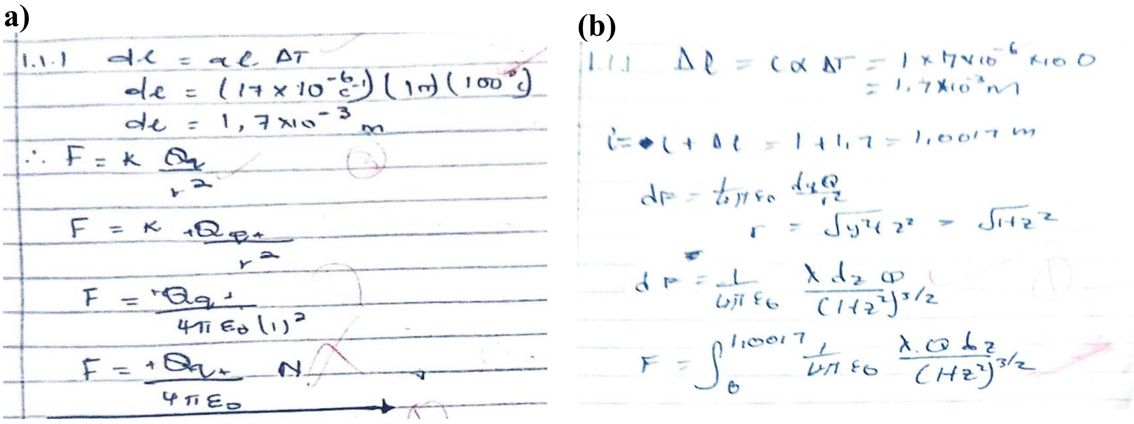
Figure 2
PPSTs Responses



The identified inaccuracy concerns epistemological and practical errors in applying Coulomb's Law. The PPST9 correctly calculated the thermal expansion of the rod (Figure 2a). However, PPST9 incorrectly used Coulomb's Law to determine the electrostatic force. This is a conceptual error since PPST9 specifically neglected the force's vector nature and failed to adjust for the expansion influencing the distances between charges adequately. PPST23 made a similar conceptual error (Figure 2b) due to a misunderstanding of the spatial encoding of machinery after expansion. In this question, PPSTs were to indicate that the force fluctuates due to the charges in the y-direction; the contained charges should have been integrated throughout the extended region; however, the PPSTs treated them as point charges. This indicates a profound conceptual knowledge difficulty. Hence, PPSTs struggled to transition from a more straightforward point charge model to a distributed charge system that employs line charge densities and calculus for integral evaluation. This finding highlights procedural and situational errors in the PPSTs' understanding of electricity and magnetism, specifically when transitioning from point charges to distributed systems. Here, the PPSTs treated the charges as point charges rather than recognizing them as distributed over a region. This reflects a failure to follow the correct procedural steps for analysing distributed charge systems, which involve integrating line charge densities over the given spatial region. The lack of integration for the extended distribution of charges suggests that PPSTs struggled to apply calculus-based techniques, which are essential for solving problems involving continuous charge systems.

Furthermore, PPSTs fail to adjust their mental models to the problem's context. While point charges are appropriate in more straightforward, isolated cases, the given situation requires an understanding of a more complex system where charges are spread across a line or region. This inability to shift from a point charge model to a distributed charge model reveals their conceptual limitations in interpreting the situation correctly.

The findings, therefore, expose a procedural error (failure to apply correct mathematical tools) and a situational error (failure to adapt to the problem's demands). This highlights the need for instructional interventions to strengthen PPSTs' conceptual and procedural knowledge of distributed charge systems in electricity and magnetism.

Errors on Electric Field Strength on the Rod

Question 1.1.2 of the test was a continuation of 1.1.1. where PPSTs were asked to determine the electric field strength on the entire rod while experiencing thermal expansion (at a temperature approximately one-third above the room temperature) pivoted at the origin along the *z*-axis, with the positive test charge placed as in question. Most PPSTs did not answer this question. Figures 3 (a) and (b) show typical PPST responses to this question.

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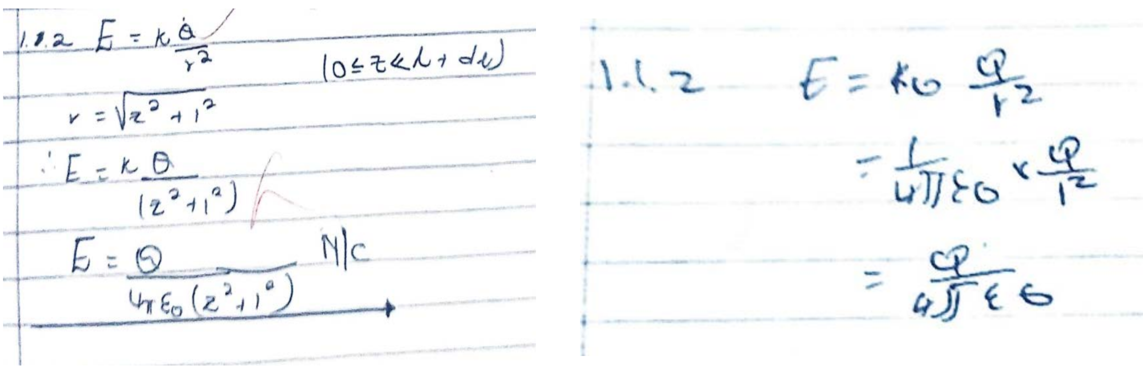
Figure 3
PPSTs Typical Responses

(a) (b)



In this case, the error stems from the incomplete application of electric field integration to a continuous charge distribution. In Figure 3, PPST56 (a) and PPST 12 (b) attempted to apply the basic electric field formula, but they failed to convert the continuous charge spread along the expanded rod into a point charge. The actual error does not lie in the shift from a discrete to a continuous charge distribution, as this is a conceptual error. Another aspect is determining the electric field strength for a charged rod, which requires integration over the rod's length (a and b).

This led to the PPSTs underestimating the exact strength of the field by systematically ignoring the contributions of every small charge element. This highlights a more complex challenge: How, for instance, do the electric fields of various sources superpose, particularly when continuous functions describe functions? A procedural error arises from incorrectly executing the mathematical steps required to determine the electric field through integration. Even if PPSTs conceptually understood that integration is needed, they failed to systematically account for the contributions of all small charge elements along the rod. This suggests a flaw in applying the correct integration steps over the rod and the length of the rod. Situational errors occurred when PPSTs failed to adapt their knowledge to the specific conditions of the problem (Figures: 3a and 3b). In this case, the rod's expanded length and distributed charge created a situation where the PPSTs needed to adapt their understanding and problem-solving strategy. This indicates an inability to appropriately modify their reasoning based on the unique setup of the problem, leading to situational error.

The findings reveal a conceptual error in understanding continuous charge distributions, a procedural error in executing the necessary integration steps, and a situational error in adapting their approach to a specific problem involving a charged rod.

Errors in Electric Potential at a Point Above a Ring

In question 1.2.1., PPSTs were asked to deduce the strength of the electric potential recorded by the electrostatic field meter containing a test charge at h meters above the xy plane as the Cu rode in question 1.1. was bent using a rod bender without discharging the rod, a ring with the total length of $l + dl$ was formed since this happens at a temperature one-third above room temperature. An electrostatic field meter containing a test charge is positioned h meters (along the z-axis) above the ring's centre, which is in the x, y plane. This is at room temperature (stress and strains are neglected). This was also a question that most PPSTs failed to answer. Figures 4 (a) and (b) show typical students' responses to this question.

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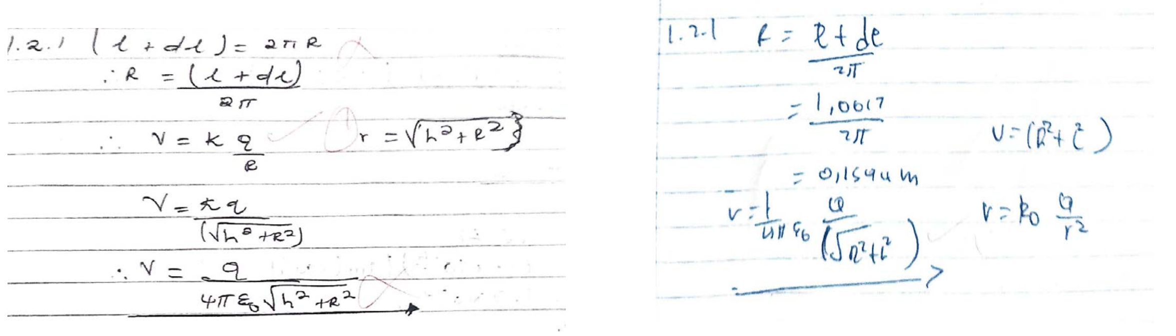
Figure 4
PPSTs Typical Responses on Electric Potential

(a) (b)



The symmetry and distance relation we use to define it give rise to this phenomenon. The PPST33 (Figure 4a) attempted to apply the potential formula for a point charge, unaware that the situation involved a ring of charges. PPST9 (Figure 4b) made an error in determining the effective distance of the test charge and the ring, leading to incorrect responses. The genesis of this mistake is not seeing the mirror image of the ring-charge configuration. Assuming symmetry greatly simplifies the problem, but it also leads to incorrect assumptions about distance and potential measurement location. Determining when to apply symmetry and when not is a greater challenge, as most PPSTs tend to overcomplicate the function by applying symmetry, making their integration more complex than necessary. This is a conceptual error because the PPSTs (PPST33 and PPST9) assumed symmetry where it may not apply, leading to incorrect assumptions about the effective distance and potential measurement location. While symmetry can simplify specific problems, misapplying it demonstrates a failure to conceptualise when and how symmetry is valid. The inability to visualize the mirror image of the ring-charge configuration also suggests a lack of conceptual understanding of spatial relationships in electric fields. Conceptual understanding of the electric field or potential due to continuous charge distributions involves integrating contributions from individual charge elements. An error about the effective distance or field point indicates a lack of understanding of how distances are defined and used in Coulomb's Law. In addition, PPST33 and PPST9 struggled with choosing when and how to use symmetry, which indicates a procedural error in their problem-solving strategy.

Common Errors Related to Magnetism

The sub-unit on electricity and magnetism typically covers a range of advanced concepts that build on fundamental electromagnetism learned in earlier years. The test covered concepts such as Magnetic Fields and Forces, Electromagnetic Induction, Magnetic Materials, Maxwell's Equations, and Electromagnetic Waves.

Errors in Magnetic Force on Wire Segments

In question 2.1, PPSTs were tasked with calculating the total magnetic force exerted on specific wire segments, based on a diagram depicting a straight conductor segment of length L orientated perpendicularly to the plane on the right, with the current flowing in opposition to the magnetic field B, succeeded by a semicircular segment with a radius of $R = 2$ m and an additional straight segment of length $L = 2$ m. The conductor transmits a current of $I = 2$A. The magnetic field $B = 2$ T is homogeneous and orthogonal to the plane of the diagram, orientated outward from the plane. Figures 5 (a) and (b) show typical responses to this question by PPSTs.

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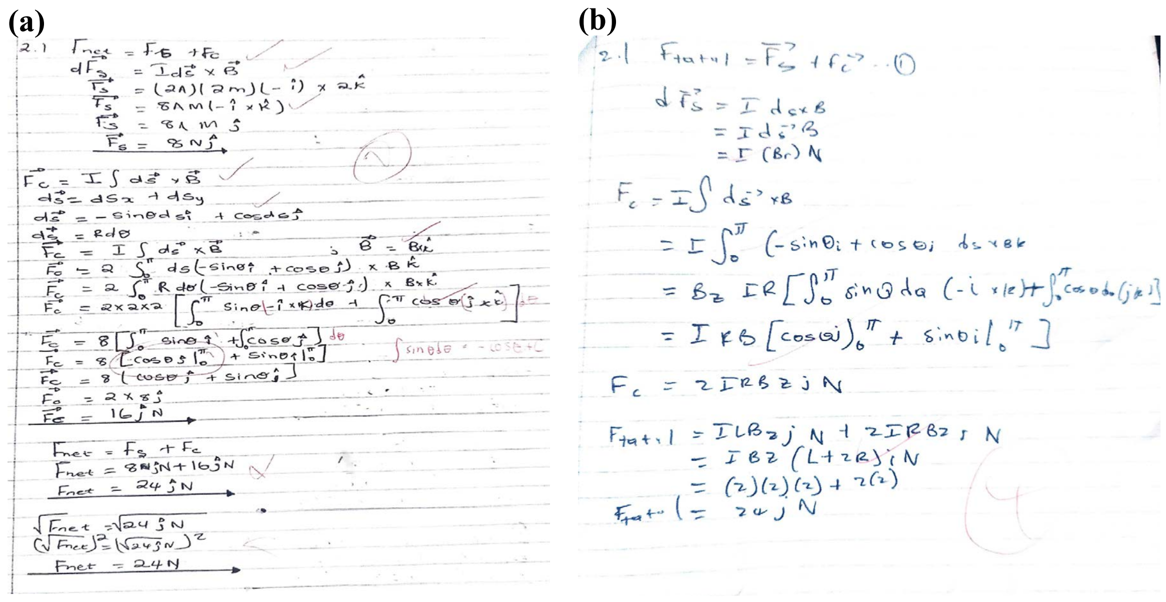
Figure 5
PPSTs' Typical Responses to Magnetic Force on Wire Segments



PPST75 response for Figure 5a was accurate. However, PPST75 did not complete the task due to conceptual difficulties. PPST75's failure to complete the task in Figure 5a points to conceptual difficulties. That was the case with most PPSTs who partially answered this question. Specifically, the inability to properly account for the curved segments indicates that PPSTs do not fully understand how magnetic force behaves on curved paths. This suggests a misunderstanding of how the magnetic force, as derived from the Lorentz force law applies when the geometry of the current-carrying conductor changes.

The lack of application of the Biot-Savart Law also reveals a conceptual gap regarding magnetic force distribution over a curved segment. PPST2 error in Figure 5b pertains to inaccurate force estimates when considering curved segments. Regarding the answers to the questions, it was evident that several of the highest-scoring PPSTs obtained a numerical value for the magnetic force on the straight segments but failed to integrate properly over the length of the semicircular segment. The right way would have been to apply the Biot-Savart Law or integrate the Lorentz force through the arc. The error arises from the assumption that the magnetic force on a curved conductor segment is identical to that on a straight segment. Since the force acting on the curve changes along it.

While PPSTs correctly obtained numerical values for the magnetic force on the straight segments, they failed to integrate appropriately over the semicircular segment. This reveals that PPSTs know how to compute forces for simple, linear segments but struggle with the procedural aspect of applying integration techniques to non-linear geometries. PPSTs did not recognize that the force on a curved segment requires integrating the force contributions along the arc using the Lorentz force or Biot-Savart Law. This procedural error is often linked to insufficient practice with problems that involve curved geometries and continuous distributions.

Error on Ampere's Law for a Long Wire

In question 2.2, Amperian loops of a long straight wire of radius *R* carrying a current *I* of uniform current density were shown to PPSTs. PPSTs were asked to use Ampere's law to find the magnetic field strength outside and inside the wire. Figure 6: (a) – (b) shows the typical responses of PPSTs based on this question.

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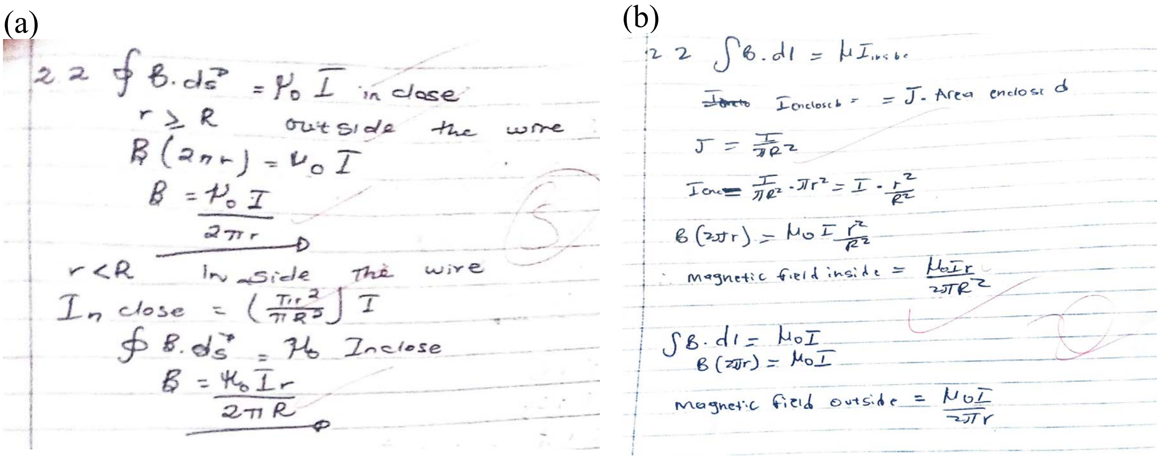
Figure 6
Ampere's Law for a Long Wire



PPST39 in Figure 6a managed to compute the values into the equation to arrive at the correct answer. However, PPST12 response in Figure 6b, indicates an incorrect configuration of Ampere's loop for both the regions inside and outside the wire shield. A conceptual error occurs when PPST12's incorrect configuration of Ampere's loop indicates a misunderstanding of how Ampere's Law operates in different regions (inside and outside the wire shield). This reveals a conceptual gap in relating current distributions to magnetic fields.

Furthermore, PPST12's failure to configure Ampere's loop correctly and differentiate between the regions inside and outside the wire points to a procedural flaw. While PPST12 might understand that Ampere's Law is used to compute magnetic fields, he misapplied the procedure for defining the loop or integrating the enclosed current, particularly when it depends on radial distance. PPST12 overlooked the detail because he was accustomed to external enclosures with uniform or straightforward currents. Of course, most PPSTs overlook this because they solely focus on understanding external enclosures.

Error on Magnetic Force on Wire in a Multi-wire Setup

In question 2.3, PPSTs were given four long straight wires which were located at the corners of a square of an area 4 cm^2. All the wires carry equal currents of 15A. Currents in the wires A and B are inwards, and C and D are outwards. PPSTs were required to determine the total magnetic force per unit length at the wire. Figure 7: (a) – (b) shows the typical responses of PPSTs based on this question.

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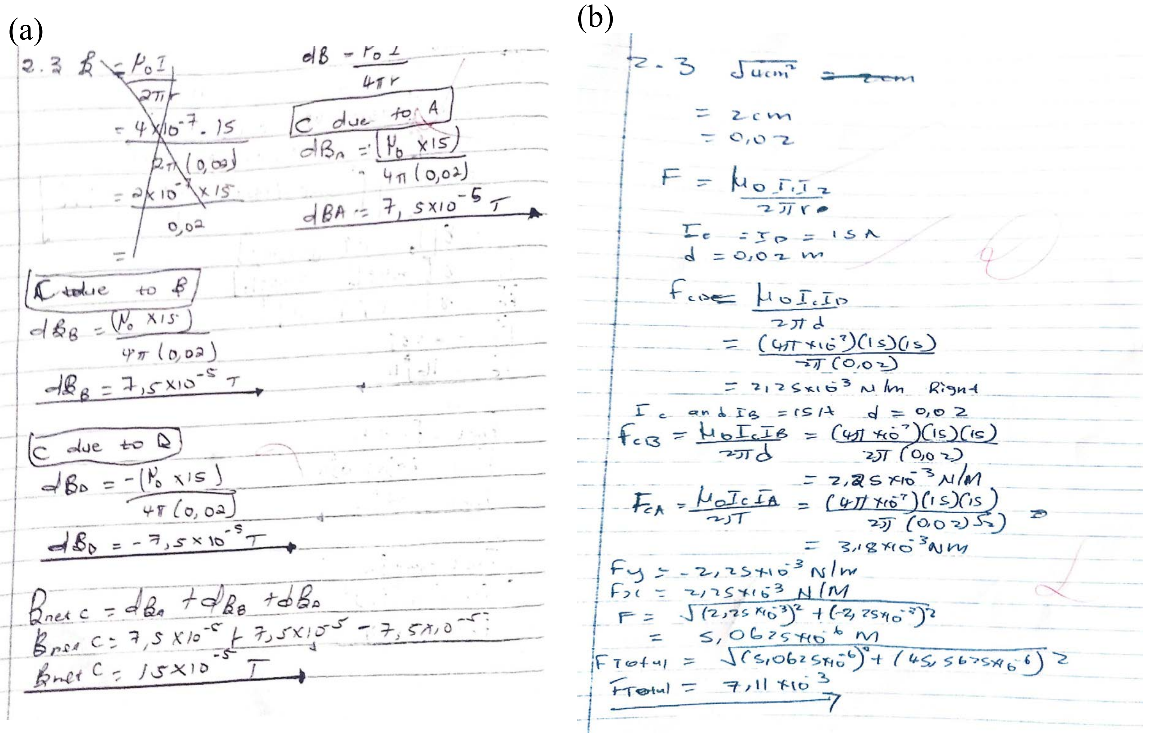
Figure 7

PPSTs Responses of Magnetic Force on Wire in a Multi-wire Setup



In this scenario, PPSTs were supposed to apply the superposition principle and vector addition of forces in solving this problem. However, the application of these principles is normally a major issue in many physics problem-solving questions. Despite PPST52 response in Figure 7b determining the correct direction of the currents, PPST52 calculated the total magnetic force incorrectly due to a misunderstanding of how forces act when more than two wires are involved. Once again, the PPST52 failed to properly account for the vector nature of the forces, leading to incorrect values resulting to a procedural difficulty in vector arithmetic. The primary issue arises when PPSTs attempt to add vectors, particularly when the forces do not form a simple rectangular shape, as shown by the PPST3 response in Figure 7a, which indicates an incomplete conceptual understanding of vector addition.

Discussion

This study examines the persistent conceptual, procedural and situational error and problem-solving challenges encountered by PPSTs in electromagnetic interactions and electromagnetic effects, emphasizing their understanding of key principles such as Ampere's and Gauss's laws, vector analysis and the superposition principle while proposing interventions to enhance their preparedness for teaching practices.

The study's findings reveal significant conceptual challenges PPSTs face in mathematical problem-solving, particularly in mastering content related to electrostatics. Many PPSTs demonstrated conceptual and procedural difficulties in grasping Coulomb's Law's foundational principles and applications. These challenges, including misinterpretations of the law's theoretical underpinnings and algorithmic missteps, are key areas where interventions can enhance PPSTs' preparedness for teaching practice. One notable example involved PPST9, which accurately calculated the thermal expansion of a rod but incorrectly applied Coulomb's Law to determine the electrostatic force. This error highlights students' challenges in correctly executing algorithmic procedures and avoiding misgeneralizations, which occur when existing concepts are misapplied to new contexts (Andriani & Nurhasanah, 2021). These findings align with prior research identifying widespread confusion and persistent alternative conceptions of electric and magnetic fields among secondary and undergraduate students (Guisasola, 2014; Hoyer & Girwidz, 2024; Zuza et al., 2018). Previous studies have indicated that misconceptions, including those related to the direc-

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tion and magnitude of forces exerted by electromagnetic fields, often originate at the high school level and remain unresolved through higher education (Dori & Belcher, 2005). Students frequently fail to recognize symmetry conditions critical for effectively using these laws (Wallace & Chasteen, 2010). As suggested by Zuza et al. (2018), there is a critical and urgent need for targeted interventions to address conceptual and procedural errors, particularly in connecting observable electromagnetic phenomena with their theoretical explanations.

In the literature, the difficulty that PPSTs face in transitioning from a more straightforward point charge model to a more complex distributed charge system, which requires the application of line charge densities and calculus-based integral evaluations, has been well-documented(Bozzo et al., 2022; Guisasola et al., 2010). This challenge highlights significant procedural and situational errors in their understanding of electricity and magnetism. This study showed that PPSTs often treat charges as point entities, failing to recognize them as distributed across a spatial region. Such misinterpretations reflect a need for more adherence to correct procedural steps, which involve integrating line charge densities over the relevant spatial dimensions (Herholdt & Sapire, 2014; Siyepu, 2013).

The procedural errors observed align with the broader category of algorithmic execution failures, encompassing incorrect operations, algorithm misapplications, and omissions of critical problem-solving steps. These errors may stem from mis-generalization, where existing concepts are applied inappropriately to new contexts (Andriani & Nurhasanah, 2021). For instance, the study found that PPSTs struggled to grasp fundamental principles and often needed to improve their application. This led to incorrect formula use, mishandling of mathematical steps, and flawed calculations. Such procedural shortcomings may result in incorrect predictions of electromagnetic forces or fields, as evidenced in earlier studies (Gülçiçek & Damlı, 2018).

Similarly, difficulties were noted in PPSTs' understanding of magnetic force on curved wire segments. While successfully computed forces for linear segments, they needed help integrating force contributions over semicircular paths. This procedural gap reveals an incomplete application of the Lorentz force law and Biot-Savart Law, particularly for non-linear geometries. Such findings resonate with studies documenting widespread misconceptions about vector fields, forces, and mathematical principles in electromagnetism (Assem et al., 2024; Mbonyiryivuze et al., 2019). The abstract nature of electromagnetic concepts, compounded by their mathematical rigour, further exacerbates these challenges. Garduza et al. (2023) have emphasised students' struggles in bridging theoretical knowledge with practical applications, particularly in electrostatics, while Rahmawati (2023) have identified the abstractness of these concepts as a key barrier. These findings underscore the need for instructional strategies that address conceptual clarity and procedural competence in electricity and magnetism.

The study further found that PPSTs struggled with foundational principles such as distinguishing fields from forces when addressing unfamiliar electric and magnetic phenomena, which aligns with prior studies. Specifically, difficulties in applying Gauss's and Ampere's laws have been widely documented. These include confusion between electric field and flux (Guisasola et al., 2008; Li & Singh, 2018a; Pepper et al., 2012), magnetic field and circulation (Bozzo et al., 2022; Guisasola et al., 2010), and the misapplication of the superposition principle by assuming only enclosed field sources contribute to the field (Li & Singh, 2018b; Pepper et al., 2012). These conceptual difficulties become pronounced in scenarios such as calculating magnetic forces in multi-wire setups. For instance, PPST52 demonstrates an inability to correctly apply the superposition principle despite determining the current directions accurately. This suggests a limited understanding of the vector nature of forces in systems involving multiple wires and magnetic fields. Such misconceptions indicate the need for targeted interventions to strengthen foundational skills, including vector calculus and field integration.

An analysis of the complexity of test items, aligned with Bloom's Taxonomy, reveals significant cognitive demands in solving and teaching physics concepts like electrostatic force, electric field intensity, and magnetic forces. Studies by Aprianti (2024) and Carpendale and Cooper (2021) advocate for an instructional focus on active engagement and conceptual clarity to bridge these gaps, emphasizing the critical nature of the issue.

Nonetheless, the findings further highlight the importance of higher-order cognitive skills as categorized by Bloom's Taxonomy and its application in complex, multi-conceptual problems which require PPSTs to operate at the *analysis* and *evaluation* levels, emphasizing the need for targeted interventions that build conceptual and procedural knowledge as advocated by De Jong and Ferguson-Hessler (1996). This study contributes to the discourse on enhancing the pedagogy of electricity and magnetism.

Conclusions and Implications

This study has revealed critical insights into common errors and conceptual, procedural and situational difficulties among PPSTs. The findings indicate that many PPSTs struggle with fundamental principles such as the

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relationship between electric and magnetic fields, applying Faraday's Law of Induction, and conceptualising forces in electromagnetic systems. These errors are often rooted in incomplete understanding, rote learning, and a lack of integration between theoretical knowledge and practical application, indicative of more profound conceptual difficulties. These errors can stem from various sources, including inadequate foundational knowledge, misconceptions formed during prior learning experiences, and the challenges of applying theoretical concepts to practical situations.

While transitioning from point charges to dispersed systems, the PPSTs made procedural and situational errors in their understanding of electricity and magnetism. Instead of understanding the charges as regional, the PPSTs treated them as point charges. This implies that distributed charge systems are not appropriately analysed by integrating line charge densities over the spatial region. This implies that PPSTs had difficulty in analysing problems and struggled to use calculus-based methods to solve continuous charge system problems. This necessitates the integration of an experiential learning methodology in the instruction of introductory physics to enhance students' conceptual understanding and critical thinking skills.

While conceptual knowledge influences procedural knowledge, the reverse relationship is also observed, indicating a bidirectional influence between the two. This iterative process of development is facilitated by improved problem representation, which aids in bridging the gap between conceptual understanding and procedural skills. Hence, a need to actively engage students in physics courses by focusing on conceptual, procedural, and situational knowledge to contribute to long-term knowledge retention. Therefore, in teaching physics, researchers recommend emphasizing conceptual knowledge over mathematical knowledge to enhance students' understanding. By focusing on conceptual understanding, teachers can support students in developing deep knowledge of physical phenomena.

The implications of these findings are significant for teacher education programs, highlighting the need for targeted interventions that address these errors or misconceptions. By integrating more comprehensive instructional strategies focusing on conceptual understanding, teacher educators can better prepare PPSTs to teach complex physics concepts effectively. Furthermore, the findings suggest that teacher educators should prioritize integrating inquiry-based learning approaches in their curricula. Such pedagogical strategies enhance content knowledge and equip future teachers with the skills necessary to facilitate student learning effectively.

In light of these implications, future research should explore the effectiveness of specific instructional interventions to address the identified errors or misconceptions. In addition, longitudinal studies could provide valuable insights into how targeted teaching strategies could influence students' conceptual understanding over time. Furthermore, expanding the scope of the study to include both high school students and undergraduate students in mainstream science could further enrich the findings and enhance the generalizability of the results.

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Declaration of Interest

The authors declare no competing interest.

References

Alihodžić, A., Mujezinović, A., & Turajlić, E. (2021). Electric and magnetic field estimation under overhead transmission lines using artificial neural networks. *IEEE Access, 9*, 105876-105891. https://doi.org/10.1109/access.2021.3099760

Anderson, O. R., Randle, D., & Covotsos, T. (2001). The role of ideational networks in laboratory inquiry learning and knowledge of evolution among seventh-grade students. *Science Education, 85*(4), 410 – 425. https://doi.org/10.1002/sce.1016

Andriani, S., Triyanto, .., & Nurhasanah, F. (2021). Procedural error of XIIth grade high school students in solving algebra problems based on Elbrink's theory. *Journal of Physics: Conference Series, 1796*(1), Article 012048. https://doi.org/10.1088/1742-6596/1796/1/012048

Aprianti, S. N. (2024). Computational Thinking-Based Calculus E-Module to Improve Students' Mathematical Literacy Skills. *Strata Social and Humanities Studies*, *2*(2), 135-148.

Assem, H. D., Owusu, M., Issah, S., & Issah, B. (2024). Identifying and dispelling students' misconceptions about electricity and magnetism using inquiry-based learning in selected junior high schools. *ASEAN Journal for Science Education*, *3*(1), 13 – 32.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Boateng, S., & Mushayikwa, E. (2022). Teaching electricity and magnetism to high school physical science learners: the effectiveness of learning style-based instructions. *PONTE International Scientific Research Journal, 78*(3). https://doi.org/10.21506/j.ponte.2022.3.1

Bollen, L., Kampen, P. V., Baily, C., & Cock, M. D. (2016). Qualitative investigation into students' use of divergence and curl in electromagnetism. *Physical Review Physics Education Research, 12*(2). Article 020134. https://doi.org/10.1103/physrevphyseducres

Bollen, L., Kampen, P. V., & Cock, M. D. (2018). Development, implementation, and assessment of a guided-inquiry teaching-learning sequence on vector calculus in electrodynamics. *Physical Review Physics Education Research, 14*(2). Article 020115. https://doi.org/10.1103/physrevphyseducres

Bozzo, G., Michelini, M., Bonanno, A., & Stefanel, A. (2022). Atwood's Machine and Electromagnetic Induction: A Real Quantitative Experiment to Analyze Students' Ways of Reasoning. *EURASIA Journal of Mathematics, Science and Technology Education*, *18*(2), Article em2077. https://doi.org/10.29333/ejmste/13273

Bruns, J., Gasteiger, H., & Strahl, C. (2021). Conceptualising and measuring domain-specific content knowledge of early childhood educators: a systematic review. *Review of Education, 9(*2), 500-538. https://doi.org/10.1002/rev3.3255

Carpendale, J., & Cooper, R. (2021). Conceptual understanding procedure to elicit metacognition with pre-service physics teachers. *Physics Education*, *56*(2), Article 025008. https://doi.org/10.1088/1361-6552/abc8fd

Çermik, H. (2020). From the Perspectives of High School Students: Difficulties in the Process of Learning Physics. *International Journal of Eurasian Education and Culture*, *5*(9), 793–822. https://doi.org/10.35826/ijoecc.144

Chi, M. T. (2005). Commonsense conceptions of emergent processes: Why some misconceptions are *robust*. *The Journal of the Learning Sciences, 14*(2), 161–199. https://doi.org/10.1207/s15327809jls1402_1

Chi, M. T. (2013). Two kinds and four sub-types of misconceived knowledge, ways to change it, and the learning outcomes. *Psychology of Learning and Motivation*, *58*, 61–82.

Choi, Y. D., & Yun, H. (2019). Visualizing electromagnetic vector fields in matter using mathematica. *Applied Science and Convergence Technology, 28*(3), 66–78. https://doi.org/10.5757/asct.2019.28.3.66

Çoştu, B., Ayas, A., & Níaz, M. (2011). Investigating the effectiveness of a poe-based teaching activity on students' understanding of condensation. *Instructional Science, 40*(1), 47–67. https://doi.org/10.1007/s11251-011-9169-2

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Sage.

De Jong, T., & Ferguson-Hessler, M. G. (1996). Types and qualities of knowledge. *Educational Psychologist*, *31*(2), 105–113. https://doi.org/10.1207/s15326985ep3102_2

DiSessa, A.A. (1988). *Knowledge in pieces*. In G. Forman & P. Pufal (Eds), *Constructivism in the computer age* (pp 49–70). Lawrence Erlbaum Associates.

Dori, Y. J., & Belcher, J. W. (2005). Learning electromagnetism with visualizations and active learning. *Visualization in Science Education*, 187–216. https://doi.org/10.1007/1-4020-3613-2_11

Duit, R. (2014). Teaching and learning the physics energy concept. *Teaching and Learning of Energy in K – 12 Education*, 67–85. https://doi.org/10.1007/978-3-319-05017-1_5

Duit, R. & Treagust, D. F. (2011). How can conceptual change contribute to theory and practice in science education?. *Second International Handbook of Science Education,* 107–118. https://doi.org/10.1007/978-1-4020-9041-7_9

Ebenezer, J., Chacko, S., Kaya, O., Koya, S. K., & Ebenezer, D. L. (2009). The effects of common knowledge construction model sequence of lessons on science achievement and relational conceptual change. *Journal of Research in Science Teaching, 47*(1), 25 – 46. https://doi.org/10.1002/tea.20295

Fauskanger, J. & Bjuland, R. (2018). Deep learning as constructed in mathematics teachers' written discourses. *International Electronic Journal of Mathematics Education, 13*(3). https://doi.org/10.12973/iejme/2705

Furió, C., & Guisasola, J. (1998). Difficulties in learning the concept of electrical field. *Science Education*, *82* (4), 511–526.

Garduza, F. A. L., Díaz, M. H. R., & Rosetti, L. G. C. (2023). Engineering Professors' Conceptions on the Conceptual Field of Electrostatics in Mexico. *International Journal of Innovation in Science and Mathematics Education*, *31*(6). https://doi.org/10.30722/ijisme.31.06.003

Griffiths, D. J. (2017). *Introduction to Electrodynamics* (4th ed.). Cambridge University Press

Guisasola, J. (2014). How physics education research contributes to designing teaching sequences. *Springer Proceedings in Physics*, 397–406. https://doi.org/10.1007/978-3-319-00297-2_39

Guisasola, J., Almudí, J. M., Salinas, J., Zuza, K., & Ceberio, M. (2008). The Gauss and Ampere laws: different laws but similar difficulties for student learning. *European Journal of Physics*, *29*(5), 1005.https://doi.org/10.1088/0143-0807/29/5/013

Guisasola, J., Zubimendi, J. L., & Zuza, K. (2010). How much have students learned? research-based teaching on electrical capacitance. *Physical Review Special Topics - Physics Education Research, 6*(2). https://doi.org/10.1103/physrevstper.6.020102.

Gülçiçek, Ç., & Damlı, V. (2018). Analysis of the behaviour of charged particles in electrical and magnetic fields by prospective physics teachers. *European Journal of Physics, 39*(6), Article 065701. https://doi.org/10.1088/1361-6404/aaddd4

Gürel, D. K., Eryılmaz, A., & McDermott, L. C. (2015). A review and comparison of diagnostic instruments to identify students' misconceptions in science. *EURASIA Journal of Mathematics, Science and Technology Education, 11*(5). https://doi.org/10.12973/eurasia.2015.1369a

Hammer, D. (1996). Misconceptions or p-prims: how may alternative perspectives of cognitive structure influence instructional perceptions and intentions. *Journal of the Learning Sciences, 5*(2), 97–127. https://doi.org/10.1207/s15327809jls0502_1

Heckler, A. F., & Sayre, E. C. (2010). What happens between pre- and post-tests: multiple measurements of student understanding during an introductory physics course. *American Journal of Physics, 78*(7), 768-777. https://doi.org/10.1119/1.3384261

Herholdt, R., & Sapire, I. (2014). An error analysis in the early grades of mathematics: A learning opportunity? *South African Journal of Childhood Education*, *4*(1), 43-60.https://doi.org/10.4102/sajce.v4i1.46

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Hernandez, E., Campos, E., Barniol, P., & Zavala, G. (2023). Students' conceptual understanding of electric flux and magnetic circulation. *Physical Review Physics Education Research*, *19*(1), Article 013102. https://doi.org/10.1103/physrevphyseducres.19.013102

Hoyer, C., & Girwidz, R. (2024). Vector representations and unit vector representations of fields: problems of understanding and possible teaching strategies. *Physical Review Physics Education Research, 20*(1). Article 010150 https://doi.org/10.1103/physrevphyseducres.20.010150

Lattery, M. J. (2016). *Deep Learning in Introductory Physics: Exploratory Studies of Model-Based Reasoning*. IAP.

Leniz, A., Zuza, K., & Guisasola, J. (2017). Students' reasoning when tackling electric field and potential in explanation of dc resistive circuits. *Physical Review Physics Education Research, 13*(1). Article 010128. https://doi.org/10.1103/physrevphyseducres

Li, J. & Singh, C. (2018). Investigating and improving introductory physics students' understanding of electric flux. *European Journal of Physics, 39(*4), Article 045711. https://doi.org/10.1088/1361-6404/aabeeb

Listiono, A. E., Tukiman, T., & Dilisti, D. (2025). Analysis Of The Quality Of Learning Achieved Through The Application Of The Inquiry Base Learning Model And Its Effect On Student Learning Interest In Science Laboratory Management And Engineering Subjects. *Journal of Multidisciplinary Research*, *1*(2), 85-92. https://doi.org/10.70963/jmr.v1i2.137

Liu, T., & Sun, H. (2021). Key Competencies of Physics Teachers. *Higher Education Studies, 11*(1), 28–33. https://doi.org/10.5539/hes.v11n1p28

Malgieri, M., Calcagnile, S., Zuccarini, G., & Onorato, P. (2021). High school student difficulties in drawing the field lines for two magnets. *Physics Education, 56*(6), Article 065007. https://doi.org/10.1088/1361-6552/ac1a06

Maloney, D. P. (1985). Rule-governed approaches to physics: conservation of mechanical energy. *Journal of Research in Science Teaching, 22*(3), 261 – 278. https://doi.org/10.1002/tea.3660220308

Maloney, D. P., O'Kuma, T. L., Hieggelke, C. J., & Van Heuvelen, A. (2021). Surveying students' conceptual knowledge of electricity and magnetism. *American Journal of Physics, 89*(9), 757–771.https://doi.org/10.1002/tea.3660220308

Maries, A., Brundage, M. J., & Singh, C. (2022). Using the conceptual survey of electricity and magnetism to investigate progression in student understanding from introductory to advanced levels. *Physical Review Physics Education Research, 18(*2). Article 020114 https://doi.org/10.1103/physrevphyseducres.18.020114

Mbonyiryivuze, A., Yadav, L. L., & Amadalo, M. M. (2019). Students' conceptual understanding of electricity and magnetism and its implications: a review. *African Journal of Educational Studies in Mathematics and Sciences, 15*(2), 55 – 67. https://doi.org/10.4314/ajesms.v15i2.5

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Mulhall, P., McKittrick, B., & Gunstone, R. (2001). A perspective on the resolution of confusions in the teaching of electricity. *Research in Science Education*, *31*(4), 575-587.https://doi.org/10.1023/a:1013154125379

Ng, Y. F., Chan, K. K., Lei, H., Mok, p., & Leung, S. (2019). Pedagogy and innovation in science education: a case study of an experiential learning science undergraduate course. *The European Journal of Social &Amp; Behavioural Sciences, 25*(2), 156–173. https://doi.org/10.15405/ejsbs.254

Nousiainen, M. (2012). Making concept maps useful for physics teacher education: Analysis of epistemic content of links. *Journal of Baltic Science Education*, *11*(1), 29–42. https://doi.org/10.33225/jbse/12.11.29

Novotná, S., & Demkanin, P. (2024). Physics teachers and use of sensors by pupils themselves, preliminary ideas of typology of physics teachers. *Journal of Physics: Conference Series, 2750*(1), Article 012042. https://doi.org/10.1088/1742-6596/2750/1/012042

Pepper, R. E., Chasteen, S. V., Pollock, S. J., & Perkins, K. K. (2012). Observations on student difficulties with mathematics in upper-division electricity and magnetism. *Physical Review Special Topics - Physics Education Research, 8*(1). https://doi.org/10.1103/physrevstper.8.010111

Pherson-Geyser, G. M., Villiers, R. D., & Kavai, P. (2020). The use of experiential learning as a teaching strategy in life sciences. *International Journal of Instruction, 13*(3), 877–894. https://doi.org/10.29333/iji.2020.13358a

Qin, W., Cheng, M., Wang, J., Zhu, X., Wang, Z., & Hua, W. (2023). Compatibility analysis among vector magnetic circuit theory, electrical circuit theory, and electromagnetic field theory. *IEEE Access, 11*, 113008-113016. https://doi.org/10.1109/access.2023.3323407

Rahmawati, R., Widiasih, W., Marisda, D. H., & Riskawati, R. (2023). Using four-tier test to identify prospective elementary teacher students' misconception on electricity topic. *Jurnal Penelitian Pendidikan IPA, 9*(10), 7793-7802. https://doi.org/10.29303/jppipa.v9i10.3272

Rittle-Johnson, B., & Alibali, M. W. (1999). Conceptual and procedural knowledge of mathematics: does one lead to the other?. *Journal of Educational Psychology, 91*(1), 175–189. https://doi.org/10.1037/0022-0663.91.1.175

Rittle-Johnson, B., Siegler, R. S., & Alibali, M. W. (2001). Developing conceptual understanding and procedural skill in mathematics: an iterative process. *Journal of Educational Psychology, 93*(2), 346 – 362. https://doi.org/10.1037/0022-0663.93.2.346

Safkolam, R., Madahae, S., & Saleah, P. (2024). The effects of inquiry-based learning activities to understand the nature of science of science student teachers. *International Journal of Instruction*, *17*(1), 479–496.https://doi.org/10.29333/iji.2024.17125a

Sangam, D., & Jesiek, B. K. (2012). Conceptual understanding of resistive electric circuits among first-year engineering students. *ASEE Annual Conference &Amp Exposition Proceedings.* https://doi.org/10.18260/1-2--21097

Sapriati, A., Rahayu, U., Sausan, I., & Sekarwinahyu, M. (2024). The impact of inquiry-based learning on students' critical thinking in biology education programs within open and distance learning systems. *Jurnal Pendidikan IPA Indonesia*, *13*(3). https://doi.org/10.15294/7sty9026

Shavelson, R. J., Phillips, D. C., Towne, L., & Feuer, M. J. (2003). On the science of education design studies. *Educational Researcher, 32(*1), 25 – 28. https://doi.org/10.3102/0013189x032001025

Siyepu, S. (2013). The zone of proximal development in the learning of mathematics. *South African Journal of Education*, *33*(2), 1–13.https://hdl.handle.net/10520/EJC134983

Smith, J. P., diSessa, A. A., & Roschelle, J. (1994). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences, 3*(2), 115–163. https://doi.org/10.1207/s15327809jls0302_1
Suárez, Á., Marti, A. C., Zuza, K., & Guisasola, J. (2024). Learning difficulties among students when applying ampére-maxwell's law and its implications for teaching. *Physical Review Physics Education Research, 20*(1). https://doi.org/10.1103/physrevphyseducres.20.010143
Turgut, Ü., Gürbüz, F., & Turgut, G. (2011). An investigation 10th grade students' misconceptions about electric current. *Procedia-Social and Behavioral Sciences*, *15*, 1965–1971. https://doi.org/10.1016/j.sbspro.2011.04.036
Vuola, K., & Nousiainen, M. (2020). Physics knowledge justification: an analysis framework to examine physics content knowledge. *Nordina: Nordic studies in science education*, *16*(2), 149–166. https://doi.org/10.5617/nordina.6916
Wallace, C. S. & Chasteen, S. V. (2010). Upper-division students' difficulties with ampère's law. *Physical Review Special Topics - Physics Education Research, 6*(2). Article 020115 https://doi.org/10.1103/physrevstper.6.020115
Wilcox, B. R., Pollock, S. J., & Bolton, D. (2020). Retention of conceptual learning after an interactive introductory mechanics course. *Physical Review Physics Education Research, 16*(1). Article 010140. https://doi.org/10.1103/physrevphyseducres.16.010140
Yin, R. K. (2018). *Case study research and applications*. Sage Publication.
Zuza, K., Kampen, P. V., Cock, M. D., Kelly, T., & Guisasola, J. (2018). Introductory university physics students' understanding of some key characteristics of classical theory of the electromagnetic field. *Physical Review Physics Education Research, 14*(2). Article: 020117 https://doi.org/10.1103/physrevphyseducres

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RISK PERCEPTION AND RESPONSE TO NATURAL HAZARDS WITHIN SCIENCE CURRICULUM

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Minchul Kim

Abstract. *Natural hazards pose global risks making it essential to incorporate risk perception and response strategies into science curricula. This study analyzed the distribution of risk perception and response indicators for natural hazards—including earthquakes, tsunamis, typhoons, landslides, floods, droughts, volcanoes, wildfires, storms, and extreme temperatures (heat waves, cold waves)—in lower secondary science curricula: the Cambridge Lower Secondary Curriculum 2020 (UK), Indonesia Merdeka Curriculum 2022, South Korea Curriculum 2022, and Singapore Lower Secondary Express and Normal (Academic) Curriculum 2021. A descriptive qualitative content analysis was conducted by analyzing curriculum documents to evaluate risk perception and response indicators distribution. The findings show that the distribution of risk perception and response to natural hazards in specific science curricula does not align with the geographic characteristics of the respective regions. Furthermore, risk perception is given greater emphasis than response strategies, creating an imbalance in the lower secondary science curriculum. This study suggests the need to modify the explanation of risk perception and response to natural hazards in the science curriculum, which emphasizes a global approach that broadens understanding beyond local hazards to prepare individuals for risks they may encounter while moving, traveling, or living in other countries.*
Keywords: *natural hazards, risk perception, risk response, science curriculum, secondary school*

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Introduction

Natural hazards affected people including children, infrastructure, and economic losses. Natural hazards cause significant risks to human life, both presently and in the foreseeable future. According to Bertoli et al. (2023), approximately 175 million children are impacted by natural hazards each year. International Federation of Red Cross and Red Crescent Societies (2022) also explained that an average of 44 countries per year, in the last 30 years, have been impacted by simultaneous disasters. Between 1994 and 2013, the Emergency Event Database (EM-DAT) recorded there were 6,973 natural disasters worldwide, and people who were affected reached 218 million annually over 20 years (Centre for Research on the Epidemiology of Disasters (CRED), 2015). In 2020, a total of 388 disasters occurred globally (Asian Disaster Reduction Center, 2023). Moreover, an earthquake occurred in the Sichuan Province with a magnitude of 8 SR, killing approximately 70,000 people, and the Kobe earthquake, in 2005, killed over 6,000 people (Asian Development Bank, 2013). Likewise, about 80% of tsunamis occur in the Pacific Ocean (Pan American Health Organization, 1994). Additionally, demographic growth, globalization, prevalent poverty, especially in hazardous areas, and dynamic climate will be causing the risk along with greater natural hazards in the future, which is associated with more population at risk (International Strategy for Disaster Reduction, 2009). For children and young people, natural hazards raise threats to their protection, physical health, and overall development (UNICEF, 2020).

In this world, various types of natural hazards have occurred and may happen in the future due to the risks that emerge from the natural disaster phenomenon. Depending on the geographic area, natural hazards occur differently. A natural hazard is defined as a natural process and event that poses a potential threat to the life of humans and property, while a disaster is described as a hazardous event that occurs within a certain zone in a limited period (Keller & Devecchio, 2015). For instance, the geographic features of the United Kingdom include hills, low mountains, rivers, and beaches (Koterba, 2019). Hills, rivers, beaches, low mountains, and plentiful rainfall all year round trigger the frequent occurrence of natural hazards such as floods (coastal flooding and river flooding), landslides, and relatively small volcanic

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eruptions (Giles, 2020; Koterba, 2019; Stock & Wentworth, 2019). The sediment along Scotland's north-eastern coasts and at locations in northeast England has been characterized as tsunami deposits and ascribed to a major submarine landslide (Giles, 2020). The most tectonically and seismically active area is at the northwest corner of Wales. However, the earthquake's seismic risk is classified as low to moderate (Giles, 2020). Summers are the warmest, reaching temperatures that can rise above 35°C in the southeast of England, which is closest to the European mainland, leading to natural hazards including droughts and heat waves (Koterba, 2019; Stock & Wentworth, 2019). Moreover, Indonesia is located near the Ring of Fire (tectonic belt, volcanic mountain) and sea (Pambudi, 2018). Since Indonesia is in the Ring of Fire, the types of natural hazards that frequently occur are earthquakes, volcanic eruptions, and tsunamis (Protschky, 2022). The geography of South Korea is along the coastlines of the south, east, and west seas, consisting of mountains, rivers, plains, and the proximity of tectonic plate boundaries along the Pacific Rim (Kwon et al., 2016; National Geographic Information Institute, 2017), which contributes to the types of natural hazards prevalent in the region including river flooding, the potential of earthquake and volcanoes (Kang & Skidmore, 2018; Kim & Yoon, 2020; National Geographic Information Institute, 2017). In addition, South Korea's geographic position also places it within the path of many typhoons that originate in the western part of the North Pacific Ocean, which bring destructive wind, waves, storm surges, heavy rain, and landslides (National Geographic Information Institute, 2017). The coldness that originated from China gathered moisture from the warmer Yellow Sea, resulting in a thick snowfall across Korea, which triggered a cold wave (National Geographic Information Institute, 2017). Additionally, in Singapore, which is mostly low-lying and flat terrain (Bai et al., 2023), the types of natural hazards that are caused by the surrounding countries are earthquakes and tsunamis in a low seismic hazard area (Lai & Tan, 2013).

Since every country has its natural hazards, reduction of the risk impact of natural hazards can be implemented through a science curriculum, particularly about the explanation of risk perception and response to natural hazards. Bertoli et al. (2023) have argued that children must cultivate awareness of natural risks to mitigate or diminish the adverse effects of these events. Moreover, according to Cerulli et al. (2020), education contributes to the reduction and alleviation of losses inflicted by disasters. Preparedness strongly depends on school education, especially science learning. According to the International Strategy for Disaster Reduction (2009), science has contributed and is recognized as an important key in the successful strategy of risk reduction. One of the subjects that has the potential to be integrated with disaster risk reduction efforts is natural science (Tyas, 2020). Risk perception is vital for adequate preparedness (Mărgărint et al., 2023). Risk perception is explained as beliefs regarding harmful potential or loss possibility (Darker, 2013). Risk perception is outlined as the competence to identify and evaluate the risk related to hazardous events (King & Blickensderfer, 2023). Studies on risk perception examined the assessments individuals make when classifying and evaluating hazardous activities (Slovic, 1987). Risk perception denotes the subjective evaluation of the likelihood of a specific accident occurring and the level of apprehension regarding its consequences (Sjöberg et al., 2004).

Further, risk responses to risk are generally placed into one of four categories, such as reduce risk, remove risk, transfer risk, or accept risk (Sweeting, 2017). Risk response planning involves formulating alternatives and identifying risk responses that reduce dangers (Javid et al., 2020). In individual and social-cultural factors, prior personal experience with natural hazards has altered how people perceive and react to danger (Luis-Angel et al., 2022). Analyzing the explanation of risk perception and response to natural hazards in the science curriculum leads to the objective of this study, to what extent students are informed about these types of natural hazards. The comprehension of perceiving the risk perception and response allows students to reduce the risk of these hazards and respond effectively to the impact. Although previous studies have explored risk perception and response strategies to natural hazards, limited research has examined how these concepts are integrated into science curricula. Most existing studies focus on general disaster education, emergency preparedness, or community resilience, but there is a lack of research analyzing whether science curricula adequately prepare students for natural hazard risks. Hence, this study analyzed the distribution of risk perception and response to natural hazards through the science curriculum. By analyzing how risk perception and response are incorporated into the science curriculum, this study intends to bridge the gap between theoretical knowledge and practical preparedness, ensuring that students can effectively perceive risks and respond appropriately to natural hazards.

Research Problem

This research problem addresses the gap by critically analyzing how risk perception and response to natural hazards are presented in science curricula. The complexities of natural hazards are not adequately explained in

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the current science curricula, which impacts the sufficient preparation of students to understand risks and the lack of decision judgment during such events. For students to effectively respond to natural hazards, it is necessary to evaluate whether the current science curriculum discussing content on natural hazards and related risk responses aligns with their practical skills and knowledge. Furthermore, analyze whether this presentation of risk perception and risk response within the science curriculum is effective in developing students' understanding and preparedness. Despite the rising frequency of natural hazards and their impact, there is limited knowledge of how effective risk perception and appropriate response strategies are taught in the science curriculum.

Research Aim and Research Questions

The purpose of this study was to analyze how risk perception and responses to natural hazards are integrated and distributed within the lower secondary science curricula. This research analyzed the risk perception and response indicators to natural hazards, including earthquakes, tsunamis, typhoons, landslides, floods, droughts, volcanoes, wildfires, storms, heat waves, and cold waves within lower secondary science curricula including four countries such as Indonesia, South Korea, the United Kingdom, and Singapore. The distribution of risk perception and risk response in the science curriculum of each country is examined.

The research questions in this study were as follows:

1. Does the lower secondary science curriculum in Indonesia, South Korea, the United Kingdom, and Singapore address risk perception and response to natural hazards in alignment with their geographic characteristics?
2. How are risk perception and response to natural hazards explained in the lower secondary science curriculum of Indonesia, South Korea, the United Kingdom, and Singapore?

Research Methodology

General Background

This research applied a descriptive qualitative research design. In a descriptive analysis, the data was labeled for summary in terms of a text, word, or short phrase (Miles et al., 2014). Content analysis was the chosen method to analyze the explanation of risk perception and response indicator to natural hazards, including earthquakes, tsunamis, typhoons, landslides, floods, droughts, volcanoes, wildfires, storms, heat waves, and cold waves, in the science curricula of Indonesia, South Korea, the United Kingdom (Cambridge Curriculum), and Singapore. Content analysis was chosen in this study because the subject of analysis consisted of curriculum documents in the form of text. Content analysis was outlined as a methodical, repeatable process for reducing a lot of text into a smaller number of content categories based on certain coding rules (Berelson, 1952). Systematically transforming many words into a concise summary of key findings was the objective of qualitative content analysis (Erlingsson & Brysiewicz, 2017). The researchers categorized and set the indicators of risk perception and response to natural hazards as shown in Table 5. This categorization and indicators were used to analyze the science curriculum document of each country. Descriptive analysis was used to report the results after the content analysis. The research was conducted from November 2023 to February 2025. This time frame allowed for the collection, analysis, and interpretation of curriculum documents from the selected countries. The scope of this study was focused on analyzing the distribution of risk perception and response indicators for natural hazards in the lower secondary science curricula of four specific countries: the Cambridge Lower Secondary Curriculum 2020 (UK), Indonesia Merdeka Curriculum 2022, South Korea Curriculum 2022, and Singapore Lower Secondary Express and Normal (Academic) Curriculum 2021. The natural hazards examined in this research included earthquakes, tsunamis, typhoons, landslides, floods, droughts, volcanoes, wildfires, storms, and extreme temperatures (heat waves and cold waves). The methodological steps in this research are shown below.

Approach

This research analyzed the risk perception and responses to natural hazards within science curriculum documents from South Korea, Indonesia, the United Kingdom, and Singapore. This study utilized an inductive content analysis method to organize and categorize the content for descriptive purposes systematically. A systematic strategy for assessing qualitative data, guided by specific objectives, was called an inductive approach (Thomas, 2006).

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Analysis Procedure

Figure 1 describes the steps of the data collection procedure in this study. The data collection procedure began with a preparation document and review of the science curriculum for Indonesia, South Korea, and Cambridge as representatives of the United Kingdom, and Singapore. These countries were chosen according to the risk impact classification shown in Table 1. Afterward, researchers identified the risk perception and risk response elements within the science curriculum of each country and categorized them into coding schemes as depicted in Table 5.

Figure 1
Data Collection Procedure

Step 1	Preparation	Sample preparation of science curriculum documents for South Korea, Indonesia, the United Kingdom, and Singapore was conducted by reviewing the Ministry of Education resources from each country, relevant textbooks, and websites related to their curricula.
	⇩	
Step 2	Review of science curriculum documents	Once the science curriculum documents were prepared, the researchers reviewed them to identify the types of natural events examined in this study, such as earthquakes, tsunamis, typhoons, landslides, floods, droughts, volcanic eruptions, wildfires, storms, heat waves, and cold waves.
	⇩	
Step 3	Creation of a framework for risk perception and response	After reviewing the curriculum, which mentioned several natural hazards (including earthquakes, tsunamis, typhoons, landslides, floods, droughts, volcanoes, wildfires, storms, heat waves, and cold waves), the researchers identified and defined a framework based on references from other research papers. According to the references, the indicator for risk perception and risk response to natural hazards was developed in alignment with science curriculum text analysis.
	⇩	
Step 4	Categorization of the framework into risk perception and response indicators	Researchers categorized the framework into: 1) categories; 2) subcategories; 3) indicators for analysis in curriculum text; and 4) example items for curriculum analysis. As a result, the categorization of the framework for risk perception and risk response was developed and used as the foundational tool in this study, as shown in Table 5.
	⇩	
Step 5	Document analysis	An analysis was conducted on the explanations of texts regarding risk perception and response to natural hazards within the science curriculum documents, based on the categorization of risk perception and response analysis indicators developed in the previous stage.
	⇩	
Step 6	Data interpretation	After analyzing the documents, the results were compiled and presented in Table 6.

Selection of Countries

The World Risk Index 2023 evaluated the risk of disasters across 193 nations, including all UN countries, which account for almost 99 percent of the global population (Bündnis Entwicklung Hilft & Institute for International Law of Peace and Armed Conflict, 2023). According to the World Risk Report (WRR) 2023 data and the classification of the risk impact of natural hazards, the countries' sampling is shown in Table 1.

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Table 1
The Selected Countries of Risk Perception and Response to Natural Hazards

Risk impact classification	Country
Very high	Indonesia
High	South Korea
Medium	United Kingdom
Very low	Singapore

According to the classification of risk impact from natural hazards in the World Risk Report Data 2023, Indonesia stands out as the nation with the highest risk impact. Closely following, South Korea is classified with a high-risk impact. The United Kingdom is positioned with a classification indicating a medium-risk impact, while Singapore, in contrast, exhibits a remarkably low-risk impact regarding natural hazards. As indicated in Table 1, this study selected countries based on risk impact classifications ranging from very high to very low. Therefore, Indonesia, South Korea, the United Kingdom, and Singapore were chosen for this research.

Selection of Natural Hazard Types

The criteria for selecting data in this study were based on the frequency of natural hazard occurrences, the number of deaths, the total number of affected humans, economic losses, and the biggest natural hazard in history to track the largest effect on the world. The selection of natural hazard types was based on the data below.

1. The data from the Centre for Research on the Epidemiology of Disasters (CRED)
2. The biggest natural hazard occurrence in history

The data on the impact of natural hazards, sorted by type in 2022, were compared to the 2002 - 2021 annual average in the world (CRED, 2022) and are shown in Table 2.

Table 2
The Data of Natural Hazards Impact in 2022 Compared to the 2002 - 2021 Annual Average in the World (CRED, 2022)

Type of natural hazards	NO*		ND*		TAH* (million)		EL* (billion US$)	
	2022	2002-2021	2022	2002-2021	2022	2002-2021	2022	2002-2021
Drought	22	16	2601	1057	106.9	70.5	2601	1057
Earthquake	31	27	1626	35124	3.6	5.5	1626	35124
Extreme tempera-ture	12	19	16416	8538	0.1	4.8	16416	8538
Flood	176	168	7954	5195	57.1	80.1	7954	5195
Landslide	17	18	403	838	0.1	0.2	403	838
Mass movement	0	1	0	37	0	0	0	37
Storm	108	104	1611	10006	16.8	36.9	1611	10006
Volcanic activity	5	6	6	90	0.1	0.3	6	90
Wildfire	15	11	76	82	0.2	0.7	76	82
Total	386	370	30693	60967	184.9	199	30693	60967

*NO: Number of Occurrences; ND: Number of Deaths; TAH: Total Affected to Humans; EL: Economic Losses

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Table 2 shows the data on natural hazard impact, including the number of occurrences, the number of deaths, the total affected to humans, and the economic losses in the world. According to the data presented in the Number of Occurrences (NO), it is evident that from 2002 – 2021 to 2022, various types of natural hazards, including droughts, earthquakes, extreme temperatures, floods, landslides, mass movements, storms, volcanic activities, and wildfires, increased in occurrence from 370 to 386 incidents. It indicates that the number of occurrences of natural hazards mentioned in Table 2 might continue to increase in the future. Owing to the prospective rise in the occurrence of disasters triggered by natural hazards, preparation is necessary to face such natural hazards. Moreover, the Number of Deaths (ND) in 2022 decreased compared to the period from 2002 – 2021; however, this number remains high. These data prove the continued loss of life resulting from the occurrence of natural hazards. Preparedness needs to be instilled and implemented to reduce the number of deaths caused by natural hazards. Additionally, the Total Affected to Humans (TAH), including physical injury, emotions, behavior, well-being, and thought, decreased slightly in 2022 compared to 2002-2021. The total number of affected humans differed by 14.1 million. Therefore, the optimization of risk management of natural hazards was required to further reduce human impact more effectively. Furthermore, the Economic Losses (EL) by these types of hazards significantly decreased from 2002 - 2021 to 2022. However, the figure of 30,693 billion US dollars still represents a considerable amount for the economic losses caused by natural hazards. Reducing the impact of these losses through risk management strategies is required. The natural hazards data in Table 2 indicates that the occurrence of these types of natural hazards will increase even further in the future and will have adverse impacts on humankind, including the number of deaths, affected individuals, and economic losses. Therefore, the types of natural hazards selected in this study included droughts, earthquakes, extreme temperatures, floods, landslides, storms, volcanic activities, and wildfires. In the case of extreme temperatures, this study considered both heat waves and cold waves. Mass movements were not considered because of their low impact and infrequent occurrence. Furthermore, according to Ayala-Carcedo (2001), the largest occurrence of natural hazards in history is illustrated in Table 3.

Table 3

The Biggest Natural Hazard Occurrence in History (Ayala-Carcedo, 2001)

Natural hazards	Area (Year)	Mortal casualties
Black death pandemics	Worldwide (1346-51)	175,000,000
Drought	India (1942)	1,500,000
Plague	Ireland (1845-47)	1,500,000
Flood	China (1887)	900,000
Earthquake	China (1556)	836,000
Typhoon	Bangladesh (1979)	500,000
Mud-flows	China (1920)	100,000
Tsunami	Krakatoa (1883)	36,417
Volcano	Mt. Pelée (1902)	29,000
Snow avalanches	Alpes (218 B.C)	19,000
Heatwaves	USA (1901)	9508
Tornado	USA (1925)	689

Based on the data obtained in Table 3, natural hazards such as typhoons and tsunamis were included in this study. The cases of the Black Death pandemic and plague were not considered in this research because these are not classified as natural hazards and were not influenced by geographic characteristics. Mudflows were considered part of landslides. Additionally, snow avalanches were not included because the selected countries for this study lacked sufficient snow conditions that could trigger snow avalanches, while tornadoes were considered as part of storms. According to these sources, this research assessed the combination of previously mentioned natural

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hazards. Hence, the typical natural hazards analyzed in this study included earthquakes, tsunamis, typhoons, landslides, floods, droughts, volcanoes, wildfires, storms, and extreme temperatures (heat waves and cold waves).

Selection of Curricula

According to the science subject at the lower secondary level, the selected curricula of the countries are shown in Table 4.

Table 4
The Selected Curricula of Risk Perception and Response to Natural Hazards

Country	Curriculum	Subject	Grade
Indonesia	Merdeka Curriculum 2022	Science	Lower secondary
South Korea	South Korea Curriculum 2022		
United Kingdom	Cambridge Lower Secondary Science 0893 Curriculum Framework 2020		
Singapore	Singapore Express and Normal (Academic) Curriculum 2021		

As outlined in Table 4, this research focused on the science curriculum for lower secondary students, typically aged between eleven and sixteen years, for each country. The lower secondary science subject was selected because the science curriculum varies at the primary and upper-secondary levels across countries. In the Indonesian curriculum, primary school students studied a mix of subjects, where the subjects were blended between science and social studies. Furthermore, at the high school level in Indonesia, the United Kingdom, and Singapore, science was divided into physics, chemistry, and biology, which differed from South Korea. In South Korea's high school curriculum, the science subjects included physics, chemistry, life science (biology), and earth science. In contrast, other countries included the study of the Earth in the geography subject, which was part of social studies. Since science had become a consistent subject at the lower secondary level across the selected countries in this study, the science curriculum of the lower secondary level was chosen for this research. Considering the diversity of curricula implemented within each country, this study limited its focus to the latest science curriculum from each nation, namely the Merdeka Curriculum 2022, in which 'Merdeka' means 'Independence,' is the latest national curriculum of Indonesia; the South Korea Curriculum 2022 of South Korea; the Cambridge Lower Secondary Science 0893 Curriculum Framework 2020 of the United Kingdom; and the Singapore Express and Normal (Academic) Curriculum 2021 of Singapore.

Framework

The framework was inspired by research conducted by Cai et al. (2023), which analyzed the connection between public disaster mitigation behavior and risk perception in Wenchuan geological hazard emergency management. The framework for risk perception and public mitigation behavior in disaster emergency management was proposed by Cai et al. (2023). It included two emergency management phases: 1) pre-disaster preparation and 2) mid-disaster emergency response. Cai et al. (2023) defined that the four primary characteristics of risk perception are perceived probability, perceived severity, fear, and self-efficacy. Perceived probability designates a person's assessment of whether a risk event might have adverse outcomes; perceived severity refers to a person's judgment regarding risk event will have severe consequences; fear implies an individual feeling if they experience a potential threat; self-efficacy is essentially a perceived assessment of handling disaster risks, which represents a person's confidence in their capacity to implement mitigation strategies and falls under the general category of risk perception (Cai et al., 2023). Participating in evacuation drills, accumulating disaster supplies, attending training on disaster prevention and mitigation, and acquiring disaster insurance are examples of proactive steps in advance of pre-disaster preparedness (Cai et al., 2023).

The framework of risk perception and response to natural hazards was compiled from various sources and references, including SCI journal research, information from UN agencies, theses, research institutes, and discussions among researchers who participated in this study. The items that were used included risk perception and pre-disaster mitigation behavior. Meanwhile, the item categorized under 'mid-disaster emergency response' was

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excluded from the framework, as most countries have established disaster management agencies that implement field training through disaster simulations in schools to enhance students' preparedness for natural hazards, which was not relevant to the analytical focus of this science curriculum text document. In most curricula, risk perception and pre-disaster mitigation behavior are introduced as foundational knowledge or initial perceptions. These concepts are emphasized as essential from an early age and are systematically integrated into the curriculum. In the risk perception subcategories, the item 'fear' was excluded due to the challenges in analyzing its indicators within the curriculum text document. Therefore, based on the references mentioned above, the framework for risk perception and risk response within science curriculum was developed as shown in Table 5.

Table 5
The Framework for Risk Perception and Risk Response for Analysis in Curriculum Text

Categories	Subcategories	Indicators for analysis in curriculum text	Example item for curriculum analysis
Risk Perception	Perceived Probability	References to likelihood or probability of natural hazards occurring in specific contexts or conveyed the processes of natural hazards occur.	"Does the curriculum include examples that highlight the probability of natural hazards, or the processes of natural hazards occur (e.g., earthquakes, floods)?"
	Perceived Severity	Emphasis on the potential impact or consequences of natural hazards on human life, the environment, and property.	"Does the text describe the severity of impacts from hazards such as tsunamis, wildfires, etc.?"
	Self-efficacy	Perceive understanding and knowledge of dealing with natural hazards, which reflect students' belief in their ability against natural hazards	"Does the curriculum provide an understanding and knowledge into students' beliefs about the actions they need to take against natural hazards?"
Risk Response:	Evacuation Drill Activities	Content related to preventive measures, such as preparedness activities, warning tools or safety drills.	"Does the curriculum encourage learning about emergency preparedness (e.g. warning system tools, evacuation drills)?"
	Storage of Disaster Response Materials	Recommendations or guidelines for storing disaster or hazard response materials like food, water, and first-aid kits.	"Does the curriculum provide activities related to creating or understanding emergency kits?"
	Disaster Mitigation Training and Publicity	Importance of spreading awareness and engaging in disaster or hazard mitigation training.	"Are there references to participating in community disaster or hazard mitigation training, discussion on reducing hazard, disaster damage, or education campaigns?"

As shown in Table 5, the framework of risk perception and response to natural hazards was used to analyze the science curriculum of each country. The element of risk perception was the inclusion of content covering the causes, risk impact, and concern about topics ranging from the perceived probability of an event to the consequences of natural hazards (Avvisati et al., 2019; Ronan et al., 2001). Risk perception indicators included attitudes concerning the likelihood, awareness, beliefs, describing natural hazards, the effect of natural hazards, explaining natural hazards, the impact of natural hazards, information flows about natural hazards, knowledge about natural hazards, severity, showing curiosity, and threat intrusiveness (Avvisati et al., 2019; Pazzi et al., 2020; Ronan et al., 2001; Yildiz, 2022). The risk response indicator showed an explanation of actions and methods to mitigate natural hazards to ensure safety including knowledge about natural disaster mitigation, response, preparedness, prevention, reconstruction, risk reduction, and risk management of natural hazards (Alfi et al., 2019; Rocha, 2021; UNESCO & UNICEF, 2012).

Science Curriculum Text Document Analysis

The science curriculum text document was analyzed beginning with the researchers, who were provided with the framework in Table 5, assessing risk perception and response indicators towards natural hazards. After the researchers familiarized themselves with the set of frameworks for risk perception and response to natural hazards, the data collection commenced, and each curriculum was analyzed utilizing the content analysis method. Each researcher marked every phrase, sentence, and explanation on the text document of this science curriculum by referring to the framework's item of risk perception and response to natural hazards in the science curriculum of each country. The discussion was extended with an invitation to the professional and research team in the field of

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science education. In this study, three researchers examined the curricula of Indonesia, South Korea, Cambridge (as representatives of the United Kingdom), and Singapore. Subsequently, the findings of the analysis were cross-checked and reviewed again in the second phase, which involved collaborative review sessions. The observation notes were consulted during the conversation to enhance the validity of the results. The coding was considered to create valid data if the codes correspond to the criteria of correct decision-making standards (Potter & Donnerstein, 1999). According to the framework for each of the items studied, the researchers independently analyzed and evaluated the classification of identification. To minimize bias and enhance the consistency of the interpretations, the data results were reviewed and voted on based on agreement and disagreement among the researchers. The level of consistency of the result was determined by comparing their classifications with each other. After analyzing the science curriculum text document, the identification results are shown in Tables 6 and 7.

Research Results

The analysis of elements related to risk perception and response framework to natural hazards in the science curriculum of Indonesia, South Korea, the United Kingdom, and Singapore is shown in Table 6.

Table 6
Risk Perception and Response Distribution to Natural Hazards in the Science Curriculum

NHP*	Indonesia Merdeka curriculum 2022		South Korea curriculum 2022		Cambridge Lower Secondary Science 0893 Curriculum Framework 2020		Singapore Express and Normal (Academic) Curriculum 2021	
	RP*	RR*	RP*	RR*	RP*	RR*	RP*	RR*
Earthquake	O	O	O	O	O		O	
Tsunami	O	O					O	
Typhoon			O	O				
Landslide								
Flood					O			
Drought					O			
Volcanoes	O		O	O	O		O	
Wildfire								
Heat wave								
Storm								
Cold wave								

*NHP: Natural Hazard Phenomenon; RP: Risk Perception; RR: Risk Response; O: appears within the science curriculum

Table 6 illustrates the result of indicators related to risk perception and response to natural hazards in the science curriculum of Indonesia, South Korea, the United Kingdom, and Singapore. It shows that within the Indonesia Merdeka Curriculum 2022, both risk perception and response indicators are evident for earthquakes and tsunamis, while for volcanoes, only the risk perception indicator is present. Similarly, the South Korea Curriculum 2022 addresses both risk perception and risk response concerning earthquakes, volcanoes, and weather-related disasters, with typhoons commonly appearing in textbooks. In the case of the Cambridge Lower Secondary Science 0893 Curriculum Framework 2020, as representative of the United Kingdom, it addresses only risk perception related to earthquakes, volcanoes, floods, and droughts. Furthermore, the Singapore Express and Normal (Academic) Curriculum 2021 includes only the risk perception of earthquakes, tsunamis, and volcanoes. In addition, risk perception and response indicators for landslides, wildfires, heatwaves, storms, and cold waves are not fully integrated into any curriculum. The detailed findings of the exposition on risk perception and responses to natural hazards in the science curricula of Indonesia, South Korea, Cambridge (representing the United Kingdom), and Singapore are shown in Table 7.

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Table 7
Risk Perception and Response in the Curriculum Text Document

Curriculum	Quoted text in the curriculum	Subcategory Identification	Categories
Indonesia Merdeka Curriculum 2022	"How do earthquakes and volcanic eruptions change human life?"	Self-efficacy	Risk perception
	"Why do not tsunamis always happen during earthquakes?"	Perceived probability	
	"Make an action campaign to anticipate before, during, and after earthquakes occur."	Disaster mitigation training and publicity	Risk response
	"Describe the effects of earthquakes and volcanoes on human life."	Perceived severity	Risk perception
	"Evaluating tsunami warning system tools and exploring other methods."	Evacuation drills activities	Risk response
South Korea Science Curriculum	"Choose and deal with the study case of a disaster such as the spread of infectious disease, chemical leaks, transportation accidents, earthquakes, volcanic eruptions and weather-related disasters, etc."	Perceived probability	Risk perception
	"Discuss ways to reduce damage, not only deal with post-mortem but also prevention and preparedness."	Disaster mitigation training, publicity, and Evacuation drills activities	Risk response
Cambridge Lower Secondary Science 0893 Curriculum Framework	"Describe how earthquakes, volcanoes, and fold mountains occur near the boundaries of tectonic plates."	Perceived probability	Risk perception
	"Describe the historical and predicted future impact of climate change, including sea level change, flooding, drought, and extreme weather events."	Perceived probability and severity	
Singapore Science Curriculum, the Singapore Express and Normal (Academic) Curriculum 2021	"Show curiosity about the destructive power of forces in nature (e.g., earthquakes, tsunamis, volcanic eruptions, tropical cyclones."	Perceived severity	

Table 7 presents the analysis and identification of risk perception and response in the curriculum text documents of Indonesia, South Korea, the United Kingdom, and Singapore. Through discussion and analysis among researchers, it was found that in Indonesia's Merdeka Curriculum 2022, as reflected in the Indonesia Science Textbooks of Lower Secondary by Lestari et al. (2021), three quotes were identified as representing risk perception, while two quotes were categorized under the risk response. In the South Korea Science Curriculum, as explained in the South Korea Curriculum 2022 - (22) Disaster and Safety (가) Achievement Standard Explanation [9과 22-01] and [9과 22-02], it shows that one quote was identified as risk perception, and another was categorized as risk response. Additionally, in the United Kingdom Science Curriculum, examples of passages of how the risk perception and response indicators were delivered in the Cambridge Lower Secondary Science 0893 Curriculum Framework, published by Cambridge Assessment International Education in 2020, showed that two quotes were identified under the risk perception category. Similarly, the Singapore Express and Normal (Academic) Curriculum 2021 [9: Application of Forces and Transfer of Energy] included a quotation focused on risk perception. According to the data analysis, it is evident that the risk perception category is prominently addressed within the science curriculum. Furthermore, the subcategories of 'perceived probability', 'perceived severity', and 'self-efficacy' are frequently emphasized within these science curricula.

The Distribution of Risk Perception and Response to Natural Hazards

The risk perception and response to natural hazards within the science curriculum of Indonesia, South Korea, the United Kingdom, and Singapore are supposed to be aligned with the natural hazards depending on their geographic characteristics. According to the research results, the findings of this research are shown in Table 8.

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Table 8
The Distribution of Risk Perception and Response to Natural Hazards

<table>
<tr><th rowspan="3">Country</th><th rowspan="3">Geography characteristics</th><th rowspan="3">Type of natural hazard</th><th colspan="6">Within the science</th></tr>
<tr><th colspan="3">Risk Perception</th><th colspan="3">Risk Response</th></tr>
<tr><th>PP*</th><th>PS*</th><th>SE*</th><th>ED*</th><th>SD*</th><th>DM*</th></tr>
<tr><td rowspan="3">Indonesia</td><td rowspan="3">Ring of fire: tectonic belt, volcanic mountain, sea</td><td>Earthquake</td><td>O</td><td>O</td><td>O</td><td>X</td><td>X</td><td>O</td></tr>
<tr><td>Tsunami</td><td>X</td><td>X</td><td>X</td><td>O</td><td>X</td><td>X</td></tr>
<tr><td>Volcanoes</td><td>O</td><td>O</td><td>O</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td rowspan="8">South Korea</td><td rowspan="8">Coastlines along the south, east, and west seas, mountains, rivers, plains, tectonic plate boundaries along the Pacific Rim, within the path of many typhoons (western part of the North Pacific Ocean), thick snow across South Korea because China gathered moisture from the warmer Yellow Sea</td><td>Typhoon</td><td>O</td><td>X</td><td>X</td><td>O</td><td>X</td><td>O</td></tr>
<tr><td>Storm</td><td rowspan="5" colspan="6">X</td></tr>
<tr><td>Wildfire</td></tr>
<tr><td>Flood</td></tr>
<tr><td>Landslide</td></tr>
<tr><td>Cold wave</td></tr>
<tr><td>Volcanoes</td><td>O</td><td>X</td><td>X</td><td>O</td><td>X</td><td>O</td></tr>
<tr><td>Earthquake</td><td>O</td><td>X</td><td>X</td><td>O</td><td>X</td><td>O</td></tr>
<tr><td rowspan="7">United Kingdom</td><td rowspan="7">Hills, low mountains, rivers, beaches, plentiful rainfall, sediment along the eastern and northern coast of Scotland, the northwest corner of Wales is, tectonic seismically active places (low-moderate seismic), during summer reach high temperatures in the southeast of England (closest to European mainland)</td><td>Flood</td><td>O</td><td>O</td><td>X</td><td rowspan="7" colspan="3">X</td></tr>
<tr><td>Drought</td><td>O</td><td>O</td><td>X</td></tr>
<tr><td>Landslide</td><td rowspan="3" colspan="3">X</td></tr>
<tr><td>Heat wave</td></tr>
<tr><td>Tsunami</td></tr>
<tr><td>Earthquake</td><td>O</td><td>X</td><td>X</td></tr>
<tr><td>Volcanoes</td><td>O</td><td>X</td><td>X</td></tr>
<tr><td rowspan="3">Singapore</td><td rowspan="3">Low-lying and flat terrain</td><td>Earthquake</td><td>X</td><td>O</td><td>X</td><td rowspan="3" colspan="3">X</td></tr>
<tr><td>Tsunami</td><td>X</td><td>O</td><td>X</td></tr>
<tr><td>Volcanoes**</td><td>X</td><td>O</td><td>X</td></tr>
</table>

**Note*: PP: perceived probability; PS: perceived severity; SE: self-efficacy; ED: evacuation drill activities; SD: storage of disaster response materials; DM: disaster mitigation training and publicity; **: Types of natural hazards that infrequently occur in their respective countries but are included in the curriculum; O: appears within the science curriculum; X: does not appear within the science curriculum

As depicted in Table 8, within the Indonesia Merdeka Curriculum 2022, the risk perception and response related to natural hazards that frequently occur in Indonesia, such as earthquakes and tsunamis, which are appropriate for the country's geographic context. However, the risk response for tsunamis does not align well with the geographic characteristics of the region. Similarly, the South Korea Curriculum 2022 appropriately addresses the risk perception and response to typhoons, which are relevant to South Korea's geographic context. However, the expressions of risk perception and response to storms, wildfires, floods, landslides, and cold waves in the science curriculum are not well-suited to the specific geography of South Korea. In addition, the curriculum includes both risk perception and risk response related to volcanoes and earthquakes, indicating that these aspects are aligned with geographic features associated with events that occur infrequently in the region. Regarding the United Kingdom and its Cambridge Lower Secondary Science 0893 Curriculum Framework 2020, the risk perception of floods and droughts aligns with the geographic characteristics of the United Kingdom. However, the risk response for floods or droughts is not mentioned. Additionally, the risk perception and response related to landslides, heatwaves, and tsunamis are not relevant to the context of the geographic characteristics of the United Kingdom. Furthermore, the curriculum addresses only the risk perception of earthquakes and volcanoes, which is appropriate for the local geography, however, it does not include a risk response to these hazards. In Singapore, the Singapore Express and Normal (Academic) Curriculum 2021 addresses only the risk perception of earthquakes and tsunamis, which are relevant to the country's geographic area. Additionally, the curriculum includes volcanoes, which are not common

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natural hazards in Singapore. This suggests that the inclusion of volcanoes is more influenced by the geographical characteristics of surrounding countries.

Discussion

The results obtained in this study indicate that the distribution of risk perception and responses to natural hazards in specific science curricula is not appropriately aligned with the geographic characteristics of the respective regions. Moreover, the study reveals an imbalance in the coverage of risk perception and response to natural hazards within the lower secondary science curriculum. According to the findings, the risk perception category is prominently addressed within the science curriculum. To achieve a more balanced perspective, it is essential not only to emphasize the risk perception but also to explore more the risk response aspect of natural hazards. Balancing both risk perception and response will enable individuals or communities to manage the impacts of inevitable natural hazards. Through this study, the explanation of risk perception and risk response to natural hazards in the science curricula of Indonesia, South Korea, the United Kingdom, and Singapore were analyzed to reduce the risk of natural hazards and increase the risk management of natural hazards within school curricula, especially the science curriculum at lower secondary. Learning about risk perception and risk response to natural hazards within the science curriculum is crucial for mitigating and reducing the impact of such natural hazards, particularly for students. Modifying the distribution of risk perception and response concerning natural hazards within the science curriculum would be advantageous.

The improvement in the distribution of risk perception and response within the science curriculum will undoubtedly enhance knowledge and mitigate the risk of natural hazards. For instance, Japan had the biggest 9.0 magnitude earthquake and tsunami in 2011, and Turkey-Syria's 7.8 magnitude earthquake in 2023. According to the Asian Disaster Reduction Center (ADRC) and the International Recovery Platform (IRP) (2011), the earthquake and tsunami in Japan killed 14,508 people. In contrast, as reported by the U.S. Geological Survey (2023), the earthquake that occurred in Turkey-Syria killed 57,340 people. These data show that Japan has prepared for the worst-case effects of earthquakes and tsunamis. Japan has a good practice of assessing the response scenarios throughout every crisis, which is significant (Jimee et al., 2019). In Japan, disaster education is incorporated within the national curriculum, and the Ministry's curriculum guidelines of 2017 increased the amount of disaster education covered in foundational disciplines like science and social science (Sakurai et al., 2020). Thus, potentially furnishing its populace with risk perception and response strategies to mitigate and confront the impact of earthquakes and tsunamis, consequently, reducing the death of people resulting from these natural hazards. In terms of infrastructure, buildings in Japan are also constructed to be earthquake resistant. Japan's measures undertaken before the disaster or natural hazards strike, for instance, the construction of embankments and other hard-soft infrastructure measures (Jimee et al., 2019). This risk perception and response to earthquakes and tsunamis have greatly aided Japan in coping effectively with the impact. Conversely, alignment with research conducted by Demir (2023) has indicated that Turkey's theoretical preparation and structure for disaster and humanitarian relief were and continue to be highly flawed. Furthermore, research conducted by Kara & Özdemir (2020) has found that the majority of students knew only a few preventive practices related to response to natural hazards, and there were notable significant differences between schools and localities. These could be the reasons why Turkey-Syria has experienced a higher number of fatalities, extensive infrastructure damage, and a greater number of casualties compared to Japan. It proves the importance of learning about risk perception and response to natural hazards in education, particularly in science.

This study suggests broadening the understanding of risk perception and response to natural hazards beyond those present within the country itself through a global curriculum in the science subject. Following the findings outlined in the PISA 2018 Science Evaluation Framework and Evaluation Instruments (Korea Institute for Curriculum and Evaluation, 2019), it is evident that national question problems constitute 60.9% of the evaluation, whereas worldwide question problems comprise 29.6%. These statistics underscore the significance of addressing national question problems in educational curricula, while also emphasizing the importance of incorporating worldwide problem-solving skills into learning objectives. Therefore, developing a global curriculum addressing risk perception and response to natural hazards would enhance global preparedness. Such a curriculum could significantly contribute to assessing students' comprehension of natural hazards, potentially mitigating the impacts of such events.

Additionally, this research can contribute to helping individuals deal with the damage caused by natural hazards while residing in or visiting another country for a trip, work, or study abroad. In line with the research conducted by Rocha et al. (2021), the study has highlighted that the majority of international students believe

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they are at risk, however, nearly all of them are unsure of how to respond. Focusing on natural hazards exclusive to the home country within the science curriculum may prove insufficient when individuals are situated in a different geographic location or characteristic. A curriculum that integrates insights into the diverse natural hazards characteristic of different regions prepares individuals to navigate unforeseen natural hazards. By recognizing the array of potential threats in various natural hazards, science education assumes a crucial role in cultivating a globally aware and resilient population.

The distribution of risk perception and response to natural hazards within science curricula is essential. However, the material on natural hazards should not be confined to science subjects alone, it can also be addressed with social curricula. For instance, the Korean social studies curriculum [9사(지리)08-03] emphasizes the importance of daily preparedness for natural hazards as shown below.

"*Identifying the geographical characteristics of natural hazards in Korea and efforts to minimize the damage and explore their responses in the event of natural hazards in various situations in daily life.*"

However, since it focuses solely on the risk response to natural hazard occurrences, it is challenging to present the process of risk perception to students through social subjects. Therefore, a scientific analysis of the phenomena that cause natural hazards, along with the exploration of risk perception through the science curriculum, is essential for preparing modern citizens. There is a need for collaboration between science and social studies to integrate risk perception and risk response into the science curriculum. According to Hodson (2021), when creating the science curriculum, it is valuable to distinguish among the four main types of learning objectives: (1) learning science, (2) learning about science and scientific practice, (3) doing science, and (4) addressing socioscientific issues (SSI). The SSI develops the critical ability to address the scientific, environmental, social, economic, personal, moral ethical elements of SSI and identify acceptable, socially responsible, and successful responses (Hodson, 2021). Organizing a collaborative activity can provide an understanding of risk perception and response related to natural hazards through a case study, such as a tsunami or a major earthquake that occurred in a certain area. Students would analyze the case and investigate how it happened from a scientific perspective. After understanding how natural hazards occur scientifically, students can comprehend information regarding natural hazard phenomena. Moreover, students can prepare themselves for mitigation steps by developing or creating a tool, such as an early warning system that applies scientific concepts. In addition, these science subject activities can be integrated with social subjects. For instance, students can explore more deeply the social impact of a major natural hazard case. Students are able to analyze how the affected community responded to the disaster, how the government and international organizations provided aid, and the socio-economic impact of the post-disaster situation. In this way, students can also learn how to minimize the large-scale social and community impact of natural hazards.

Conclusions and Implications

This study analyzed the distribution of risk perception and response towards natural hazards (earthquakes, tsunamis, typhoons, landslides, floods, droughts, volcanoes, wildfires, storms, heat waves, and cold waves) is addressed within the lower secondary science curricula of Indonesia, South Korea, the United Kingdom, and Singapore. This research aims to enhance the coverage of risk perception of natural hazards and strategies for responding and reducing its impact within the science curriculum.

The results obtained in this study indicate that the distribution of risk perception and responses to natural hazards in specific science curricula is not appropriately aligned with the geographic characteristics of the respective regions. Moreover, the study reveals an imbalance in the coverage of risk perception and response to natural hazards within the lower secondary science curriculum. According to the findings, the risk perception category is prominently addressed within the science curriculum.

This study underscores the importance of balancing risk perception and response within the science curriculum to ensure a comprehensive understanding of natural hazards. A well-structured curriculum that integrates both aspects will better equip students to deal with natural hazards. Furthermore, the incorporation of global perspectives on risk perception and response within science curricula is crucial in preparing students for the diverse natural hazards they may encounter beyond their home countries. Internationally, it impacts individuals who travel, live abroad, or vacation outside their home countries, where natural hazards may differ. These individuals can develop risk perceptions and response strategies for unexpected natural hazard events. For instance, if an individual comes from a country with few coastlines and infrequent earthquakes, but then moves to a country like Japan, where

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earthquakes and tsunamis are common, they need to be provided with knowledge about the associated risks and proper evacuation procedures to respond to these natural hazards. Additionally, collaboration between science and social studies is also necessary to provide a holistic approach to disaster education. Interdisciplinary learning activities, such as case studies and problem-solving tasks, can enhance students' understanding of the scientific, social, and economic dimensions of natural hazards. This study recommends revising the science curriculum to ensure a balanced distribution of risk perception and response. By incorporating a more integrated and interdisciplinary approach to disaster education, schools can help students develop the knowledge and skills necessary to anticipate, prepare for, and respond to natural hazards effectively.

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Declaration of Interest

The authors declare no competing interest.

References

Alfi, M., Darsiharjo., & Maryani, E. (2019). Development of natural disaster mitigation teaching materials to improve understanding of disasters. *Journal of Physics: Conference Series, 387*, Article 012079. https://doi.org/10.1088/1742-6596/1387/1/012079

Asian Development Bank. (2013). *The rise of natural disasters in Asia and the Pacific*. Independent Evaluation.

Asian Disaster Reduction Center & International Recovery Platform (IRP). (2011). *Great East Japan earthquake: Preliminary observations*. United Nations Office for Disaster Risk Reduction (UNDRR). https://www.undrr.org/publication/great-east-japan-earthquake-preliminary-observations

Asian Disaster Reduction Center. (2023). *Natural disaster databook 2022 an analytical overview*. Asian Disaster Reduction Center (ADRC). https://www.adrc.asia/publications/databook/DB2022_e.php

Avvisati, G., Sessa, E. B., Colucci, O., Marfè, B., Marotta, E., Nave, R., Peluso, R., Ricci, T., & Tomasone, M. (2019). Perception of risk for natural hazards in Campania Region (Southern Italy). *International Journal of Disaster Risk Reduction, 40*, Article 101164. https://doi.org/10.1016/j.ijdrr.2019.101164

Ayala-Carcedo, F. G. (2001). Natural disasters mitigation in the world and sustainable development: A risk analysis approach. *Boletin Geológico y Minero, 112*(4), 43–64. https://app.ingemmet.gob.pe

Bai, Z., Wang, Y., Li, M., Sun, Y., Zhang, X., Wu, Y., Li, Y., & Li, D. (2023). Land subsidence in the Singapore coastal area with long time series of TerraSAR-X SAR data. *Remote Sens, 15*, Article 2415. https://doi.org/10.3390/rs15092415

Berelson, B. (1952). *Content analysis in communication research*. Free Press.

Bertoli, A., Ng'asike, J. T., Amici, S., Madjar, A., & Tesar, M. (2023). Decolonizing western science education and knowledge in early childhood: Rethinking natural hazards and disasters framework through indigenous 'ecology of knowledges' in Kenya. *Global Studies of Childhood, 14*(2). 197–213. https://doi.org/10.1177/204361062311997

Bündnis Entwicklung Hilft & Institute for International Law of Peace and Armed Conflict. (2023). *World risk report 2023*. Bündnis Entwicklung Hilft.

Cai, J., Hu, S., Sun, F., Tang, L., Fan, G., & Xing, H. (2023). Exploring the relationship between risk perception and public disaster mitigation behavior in geological hazard emergency management: A research study in Wenchuan county. *Disaster Prevention and Resilience, 2*(201). http://dx.doi.org/10.20517/dpr.2023.26

Cambridge Assessment International Education. (2020). *Curriculum Framework Cambridge Lower Secondary Science 0893 Version 1*. https://cambridge-community.org.uk/guide-to/cambridge-lower-secondary/science/

Centre for Research on the Epidemiology of Disasters (CRED). (2015). *The human cost of natural disasters a global perspective*. The United Nations Office for Disaster Risk Reduction. https://www.preventionweb.net/publication/human-cost-natural-disasters-global-perspective

Centre for Research on the Epidemiology of Disasters (CRED). (2022). *2022 Disasters in numbers*. The United Nations Office for Disaster Risk Reduction https://www.preventionweb.net/quick/76957

Cerulli, D., Scott, M., Aunap, M., Kull, A., Pärn, J., Holbrook, J., & Mander, Ü. (2020). The role of education in increasing awareness and reducing impact of natural hazards. *Sustainability, 12*(18), Article 7623. https://doi.org/10.3390/su12187623

Darker, C. (2013). Encyclopedia of behavioral medicine. In M. D. Gellman & J. R. Turner (Eds.), *Risk perception*. Springer. https://doi.org/10.1007/978-1-4419-1005-9_866

Erlingsson, C., & Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *African Journal of Emergency Medicine, 7*(3), 93-99. https://doi.org/10.1016/j.afjem.2017.08.001

Giles, D. P. (2020). Chapter 1 introducing to geological hazards in the UK: Their occurrence, monitoring and mitigation. *Geological Society, London, Engineering Geology Special Publications, 29*, 1–41. https://doi.org/10.1144/EGSP29.1

Hodson, D. (2021). Going beyond STS education: Building a curriculum for sociopolitical activism. *Canadian Journal of Science, Mathematics and Technology Education, 20*, 592–622. https://doi.org/10.1007/s42330-020-00114-6

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

International Federation of Red Cross and Red Crescent Societies. (2022). *World disasters report 2022*. International Federation of Red Cross and Red Crescent Societies. https://www.ifrc.org/document/world-disasters-report-2022

Javid, A. A., Fateminia, S. H., & Gemünden, H. G. (2020). A method for risk response planning in project portfolio management. *Project Management Journal*, *51*(1), 77–95. https://doi.org/doi.org/10.1177/8756972819866577.

Jimee, G. K., Meguro, K., & Dixit, A. M. (2019). Learning from Japan for possible improvement in existing disaster risk management system of Nepal. *Open Journal of Earthquake Research, 8*(2). https://doi.org/10.4236/ojer.2019.82006

Kang, S. H., & Skidmore, M. (2018). The effects of natural disasters on social trust: Evidence from South Korea. *Sustainability, 10*(9). https://doi.org/10.3390/su10092973

Kara, I., & Özdemir, N. (2020). Hazard perception and disaster information of Turkish secondary school students. *Journal of Education in Black Sea Region, 6*(1). https://doi.org/10.31578/jebs.v6i1.220

Keller, E. A., & DeVecchio, D. E. (2015). *Natural hazards: Earth's processes as hazards, disasters, and catastrophes* (4th ed.). Pearson Education.

Kim, D., & Yoon, H. (2020). Demographic effects of climate-induced disasters in South Korea: Spatiotemporal approach. *International Journal of Disaster Risk Reduction, 50*. https://doi.org/10.1016/j.ijdrr.2020.101837

King, J. M, & Blickensderfer, E. L. (2023). Chapter 20 – Human factors in general aviation weather. *Human Factors in Aviation and Aerospace (Third Edition)*, 543–562. https://doi.org/10.1016/B978-0-12-420139-2.00017-4

Korea Institute for Curriculum and Evaluation. (2019). *OECD programme for international students assessment: An analysis of PISA 2018 results* (RRE 2019-11). https://www.kice.re.kr/resrchBoard/view.do?seq=43767&s=kice&m=030103

Korean Ministry of Education. (2022). *Science curriculum* (proclamation of the Ministry of Education #2022-33 [Annex 9]). https://ncic.re.kr/english/dwn/ogf/inventoryList.cs

Koterba, K. (2019). *International study guide series united kingdom*. Montana State University and Montana 4-H Center for Youth Development.

Kwon, S., Kim, J., Lee, E., & Jung, C. (2016). *Geography of Korea* (D. Kane, Trans.). The Academy of Korean Studies.

Lai, A. Y. H., & Tan, S. L. (2014). Impact of disasters and disaster risk management in Singapore: A case study of Singapore's experience in fighting the SARS epidemic. *Resilience and Recovery in Asian Disasters: Community Ties, Market Mechanisms, and Governance, 18*, 309–336. https://doi.org/10.1007/978-4-431-55022-8_15

Lestari, S. H., Inabuy, V., Sutia., Maryana, O. F., & Hardanie, B. D. (2021). *Buku panduan guru ilmu pengetahuan alam* [Teacher's guidebook for natural sciences]. Pusat Perbukuan.

Mărgărint, M. C., Kovačić, S., Albulescu, A., & Miljković, Đ. (2023). Natural multi-hazard risk perception and educational insights among Geography and Tourism students and graduates amid the COVID-19 pandemic. *International Journal of Disaster Risk Reduction, 86*. https://doi.org/10.1016/j.ijdrr.2023.103549

Miles, M. B., Huberman, M. B., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). SAGE Publications.

Ministry of Education Singapore. (2020). *Science syllabuses lower secondary express course normal (academic) course implementation starting with 2021 secondary one cohort*. https://www.moe.gov.sg/secondary/courses/express/electives

National Geographic Information Institute. (2017). *The national atlas of Korea for children*. Ministry of Land, Infrastructure and Transport.

Pan American Health Organization. (1994). *A world safe from natural disasters: The journey of Latin America and the Caribbean*. Pan American Health Organization.

Pazzi, V., Morelli, S., & Bonati, S. (2020). *Disaster risk perception knowledge base – a consolidated understanding of disaster risk perception in social media and crowdsourcing research report*. European Uninon's Horizon. http://links-project.eu/deliverables/

Potter, W. J., & Levine-Donnerstein, D. (1999). Rethinking validity and reliability in content analysis. *Journal of Applied Communication Research, 27*(3), 258–284. https://doi.org/10.1080/00909889909365539

Protschky, S. (2022). Disaster in Indonesia: Along the fault line toward new approaches. *Indonesia*, *113*, 1–8. https://doi.org/10.1353/ind.2022.0000

Rocha, E. L. S. (2021). *Risk perception and response among international students of the University of Southern Mississippi* [Master's thesis, University of Southern Mississippi]. USM Campus Repository. https://aquila.usm.edu/masters_theses/857

Ronan, K. R., Johnston, D. M., Daly, M., & Fairley, R. (2001). School children's risk perceptions and preparedness: A hazard education survey. *The Australasian Journal of Disaster and Trauma Studies, 2001*(1). https://www.massey.ac.nz/~trauma/issues/2001-1/ronan.htm

Sakurai, A., Sato, T., & Murayama, Y. (2020). Impact evaluation of a school-based disaster education program in a city affected by the 2011 great East Japan earthquake and tsunami disaster. *International Journal of Disaster Risk Reduction, 47*. https://doi.org/10.1016/j.ijdrr.2020.101632

Sjöberg, L., Moen, B. E., & Rundmo, T. (2004). *Explaining risk perception: An evaluation of the psychometric paradigm in risk perception research*. Rotunde.

Slovic, P. (1987). Perception of risk. *Science, 236*(4799), 280–285. https://doi.org/10.1126/science.3563507

Stock, M., & Wentworth, J. (2019). *Evaluating UK natural hazards: the national risk assessment*. UK Parliament Post. https://doi.org/10.58248/PB31

Sweeting, P. (2017). *Financial enterprise risk management*. Cambridge University Press. https://doi.org/10.1017/9781316882214.017

Thomas, D. R. (2006). A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation*, *27*(2), 237–246. https://doi.org/10.1177/1098214005283748

Tyas, R. A., P, Suyanta. (2020). Integrating disaster risk reduction with science education to student of junior high school in Merapi Mountain areas, Indonesia. *International Journal of Engineering Research and Technology, 13*(12), 4551–4557. http://www.irphouse.com/

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

U.S. Geological Survey. (2023). *Frequently asked questions about 2023 earthquakes in Türkiye*. Earthquake Hazards Program. https://www.usgs.gov/programs/earthquake-hazards/science/frequently-asked-questions-about-2023-earthquakes-turkiye
UNESCO & UNICEF. (2012). *Disaster risk reduction in school curricula: Case studies from thirty countries*. UNICEF. https://unesdoc.unesco.org/ark:/48223/pf0000217036
UNICEF. (2020). *Disasters and natural hazards: How to prepare, respond and recover*. UNICEF. https://www.unicef.org/easterncaribbean/reports/disasters-and-natural-hazards
International Strategy for Disaster Reduction. (2009). *Reducing disaster risks through science: Issues and actions*. United Nations Office for Disaster Risk Reduction. https://www.undrr.org/quick/11087
Yildiz, A. (2022). *Analysing children's natural hazard risk perception and preparedness using a modified PRISM Approach* [Master's thesis, University of Portsmouth]. UoP Campus Repository. https://researchportal.port.ac.uk/en/studentTheses/analysing-childrens-natural-hazard-risk-perception-and-preparedne

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TEACHERS' KNOWLEDGE AND BELIEFS ABOUT GAMIFICATION IN PHYSICS CLASSROOMS

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Abstract. *Gamification has been gaining attention in STEM education for its potential to enhance student engagement and learning outcomes. Teachers' acceptance and effective use of gamification depend on their knowledge and beliefs about its implementation. This study employs a mixed-method design to explore Croatian physics teachers' knowledge and beliefs about gamification. In the first phase, semi-structured interviews were conducted with five primary and five secondary school teachers. Insights from these interviews informed the development of an online questionnaire in Google Docs. The final questionnaire consisted of three parts: demographic information (including an open-ended question defining gamification), 16 Likert-type items measuring knowledge and beliefs, and three open-ended questions on key elements, technological tools, and challenges in applying gamification in physics classrooms. In the second phase, quantitative data were collected from 230 primary and secondary school physics teachers, providing a robust sample to examine variations in knowledge and beliefs about gamification. Findings reveal that most teachers possess basic knowledge and hold positive beliefs regarding gamification, although significant differences emerge based on age, teaching experience, and school type. These results underscore the need for tailored professional development programs. The study emphasizes the importance of designing support strategies that accommodate diverse teacher profiles.*

Keywords: *gamification knowledge, mixed-method design, physics teachers, STEM education*

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Introduction

Comprehending physics is crucial in today's rapidly changing technological landscape, as it underpins the innovations shaping our world. As a foundational school subject, physics explains the laws governing the natural world and provides the basis for many technological advancements (Bao & Koenig, 2019). Additionally, it promotes the development of essential skills in learners, such as problem-solving, technological proficiency, and an innovative mindset – all of which are crucial for navigating the challenges of an increasingly digital society.

Moreover, physics education plays a central role in preparing individuals for careers across a wide range of fields, industries, and organizations. As such, its objectives extend beyond imparting subject-specific knowledge to also fostering a broad set of competencies, including knowledge, skills, attitudes, and values. This shift reflects the evolving demands of modern educational and professional environments, as scientific reasoning and digital literacy have become integral to physics curricula worldwide over the past decade (Asrizal et al., 2023; Thoms et al., 2023). However, many physics programs have not sufficiently emphasized the multidisciplinary applications of physics or addressed the broad professional opportunities available to graduates. This lack of alignment has highlighted the need for educational systems to integrate transdisciplinary and interdisciplinary approaches in physics classrooms (Cayless & Jordan, 2024).

One approach to teaching physics that supports these goals is the integration of gamification. This strategy applies game design elements to non-game contexts and has been explored as a potential solution for enhancing student engagement and learning outcomes in physics education. Previous studies have shown that gamification can effectively boost motivation, improve cognitive outcomes, and address challenges such as disengagement in STEM subjects (Dichev & Dicheva, 2017; Swacha, 2021).

However, despite the growing interest in gamification as a strategy to enhance physics education, limited attention has been given to understanding teachers' knowledge and beliefs about gamification and how these factors influence its implementation in the classroom. Teachers play a pivotal role in the success of innovative teaching strategies, yet their beliefs and knowledge about gamification remain largely unexplored.

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Theoretical Background

Physics education plays a pivotal role in addressing societal challenges and fostering skills necessary for thriving in an interconnected world. In this context, the Physics for Society at the Horizon of 2050 initiative emphasizes equipping individuals with scientific literacy and problem-solving abilities to actively participate in democratic processes and contribute to a diverse scientific workforce (Hidalgo & Lee, 2022). Similarly, the European Physics Society's Physics Education Division underscores that investing in physics education today ensures communities are prepared for the demands of a technology-driven future (Byun & Lee, 2014; Hidalgo et al., 2024).

Physics education serves a dual purpose: it prepares future physicists while also fostering scientifically literate citizens who are capable of understanding and addressing complex global challenges (DeWitt, 2016). However, many students struggle with physics concepts due to deeply ingrained misconceptions formed through everyday experiences (McDermott & Redish, 1999). These misconceptions often conflict with the scientific models taught in schools, making the subject particularly difficult for students to master (Novak & Gowin, 1984).

Interdisciplinary approaches, especially within STEM education, have proven effective in cultivating cross-cutting skills such as collaboration, self-regulation, problem-solving, creativity, communication, and critical thinking (McLoughlin et al., 2020). At the same time, constructive approaches to education emphasize active, team-based learning, which allows students to build knowledge and develop advanced cognitive abilities, such as scientific reasoning and deep subject understanding. These approaches have been shown to be particularly effective when complemented by modern technologies that enhance access to information and create more efficient learning environments (Bao & Koenig, 2019).

However, the global shortage of qualified primary and secondary school physics teachers to implement the above approaches in classrooms remains a significant issue, adversely affecting the quality of physics education (Cayless & Jordan, 2024; Erceg et al., 2023). Addressing these challenges requires innovative teaching practices that align with modern educational needs and emphasize the relevance of physics in solving real-world problems.

What is the situation in the field of physics education in Croatia? Physics is perceived as one of the least popular and most challenging subjects. This perception is largely attributed to its abstract, math-intensive nature and the volume of content presented in traditional teaching methods (Marušić & Sliško, 2009; Simel, 2016). Disinterest in physics is frequently associated with the subject's perceived dullness, although higher-achieving students tend to express greater enthusiasm (Ćosić, 2015; Simel, 2016). Many students appreciate physics for its experimental aspects and its contribution to scientific thinking but rarely pursue it as a career. Additionally, while girls tend to outperform boys academically, boys report lower motivation to engage with physics (Jugović, 2010). These trends reflect a broader, decades-long decline in interest in science education globally (Simel, 2016). Meanwhile, physics teachers report that while they can adapt to the current circumstances, they still struggle to motivate students to engage and learn (Štibi et al., 2021).

Outside of Croatia, gamification—the application of game design elements to non-gaming contexts—has emerged as a promising strategy for fostering student engagement (McGonigal, 2010). By incorporating game elements such as goals, feedback, and challenges, gamification motivates students to pursue learning actively (Deterding et al., 2011).

Research has demonstrated that gamified teaching techniques can increase engagement, improve motivation, and even lead to behavioral changes (Dichev & Dicheva, 2017; Dziob, 2018; Su, 2019; Susman & Pavlin, 2020; Swacha, 2021). Some recent science education studies have explored free-choice games, which allow students and the public to implicitly learn scientific concepts, including physics (TERIC, 2020; Vieyra et al., 2020). However, research has also highlighted that these effects can vary based on individual student characteristics.

Research in the field of gamification is highly dynamic. Jantakoon et al. (2024) have analyzed trends in gamification research, identifying significant growth in its application within STEAM education and highlighting its impact on collaborative learning. For example, gamification combined with team-based learning has been shown to improve the educational experience for students with and without special needs (Brecl et al., 2024). Meanwhile, Kam and Umar (2023) have explored the differing impacts of gamification on high- and low-achieving students, emphasizing the need for adaptive strategies to ensure equitable benefits across diverse learner groups.

From the literature review, it is evident that gamification has also been successfully implemented in diverse educational settings, such as professional foreign language training (Zvarych et al., 2019), business informatics using Moodle platforms (Paľová & Vejačka, 2022), engineering fundamentals (Song et al., 2017), and physics courses focused on electric resistors for second-year students (Forndran & Zacharias, 2019). Inquiry-based approaches, like the 5E model and escape rooms, have incorporated gamified elements to foster curiosity and active learning in

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science classes (Rusevska et al., 2024). Moreover, during the era of social distancing, studies have emphasized the sustainability and effectiveness of gamified learning environments (Musyaffi et al., 2022). Beyond these approaches, tools like Socrative for assessments (Perera & Hervás-Gómez, 2021), interactive gaming platforms (Soboleva et al., 2018), and augmented reality in STEM education (Brooks et al., 2019) demonstrate the diverse applications of gamification in enhancing teaching and learning outcomes. It has been reported that gamification is particularly effective as a teaching tool for intrinsically motivated students (Buckley & Doyle, 2016). In higher education, gamification has been applied to enhance academic knowledge acquisition and soft skills development, ensuring students remain engaged and enjoy learning (Forndran & Zacharias, 2019; Jantakoon et al., 2024).

While meta-analyses have confirmed the positive cognitive effects of gamification, motivational and behavioral outcomes vary depending on the context and design (Sailer & Homner, 2020). Similarly, Bai et al. (2020) have reported varying outcomes. The success of gamification depends heavily on careful design and implementation. Poorly constructed gamified activities can lead to negative outcomes, such as anxiety, frustration, or a perceived lack of value.

In the design and successful integration of gamification into teaching practices, teachers play a central role. Their knowledge and beliefs significantly influence how gamification is implemented in classrooms (Ketelhut & Schifter, 2011), revealing its potential to enhance both engagement and skill development. For instance, López et al. (2021) have found that nearly 80% of mathematics teachers view gamified activities in STEAM education as more effective than traditional methods, particularly in fostering positive emotional attitudes toward mathematics and developing mathematical literacy. This highlights the broader applicability of gamification across subjects and its potential to address skill gaps in STEM education.

However, many teachers lack the training and professional development opportunities to effectively implement gamified strategies (Mukh et al., 2023). Research has highlighted that providing teachers with the skills to navigate online resources and design gamified learning activities is critical for fostering future-ready science education (Bellocchi et al., 2024; Walraven et al., 2009).

This leads to the research problem addressed in this study: the limited understanding of teachers' knowledge and beliefs about gamification in physics education and its implications for effective implementation. While gamification has shown promise in enhancing engagement and learning outcomes, there remains a gap in understanding how teacher-related factors influence its success.

The aim of this study was to explore teachers' self-assessed knowledge and beliefs about gamification in physics education. By addressing these aspects, the study seeks to provide valuable insights into the factors that influence the adoption and effectiveness of gamification strategies in teaching.

The research specifically addressed the following research questions:

1. How do teachers self-assess their knowledge and beliefs about gamification?
2. Are there significant differences in knowledge and beliefs about gamification based on teachers' age, gender, work experience, and school type?
3. What effective game elements, useful tools, and challenges do teachers identify in relation to implementing gamification?

Research Methodology

General Background

To address the posed research questions, a descriptive cross-sectional study has been conducted (Cohen et al., 2002). The research employed a mixed-methods approach, emphasizing quantitative data collection and analysis, complemented by qualitative insights (Ary et al., 1972; Johnson & Christensen, 2019). The study has been conducted from February to April 2024 and targeted a substantial sample of physics educators to provide a broad understanding of gamification in physics education in Croatia.

The study has been conducted using an online questionnaire. It consisted of open-ended questions and Likert-type items. Quantitative data gathered through this facilitated an analysis of teachers' familiarity with gamification, the specific gamified elements they have used in their physics classrooms, and their knowledge and beliefs about gamification's impact on student engagement and interest. Additionally, qualitative data from open-ended questions (Creswell & Guetterman, 2019) provided deeper insights into the challenges teachers face in implementing gamification, their preferences for gamified elements in physics education, and the technological tools or applications they find most effective.

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It should be emphasized that the study has been grounded in a theoretical framework that highlights teachers' knowledge and beliefs about gamification as a critical factor influencing the successful integration of innovative teaching practices. The scope of the study extends to exploring the practical applications of gamification and its implications for improving physics education.

Sample

A total of 230 physics teachers participated in the study, representing 25% of all physics teachers in the Republic of Croatia (N = 922) for the 2023–2024 school year. The sample size was calculated using an online sample size calculator with the following parameters: confidence level of 95%, margin of error of 5%, and population proportion of 50%. Based on these settings, the sample size for a population of 922 physics teachers was determined to be 272. Although the actual sample size of 230 respondents is below the determined, it still ensures a high level of reliability for the study's findings. Research indicates that achieving at least 80% of the calculated sample size provides sufficient statistical power and validity in survey-based studies (Andrade, 2020).

The demographic information of the respondents is presented in Table 1. The respondents represented diverse educational and professional backgrounds: 53% worked exclusively in primary schools, 40% in secondary schools, and 7% taught at both primary and secondary schools. Among the respondents, 81% (187 teachers) held a university degree in physics teaching, either independently or combined with another subject; 10% (24 teachers) had completed a degree in physics/astrophysics/biophysics/computer physics with additional pedagogical training; 6% (13 teachers) held degrees in other fields with added pedagogical competencies; and 3% (6 teachers) reported having a master's degree or doctorate in physics, educational physics, or didactics.

The respondents' age distribution and work experience ensured a balanced representation of the teaching population (Table 1). Two respondents did not provide their age, which accounts for the discrepancy between the total sample size of 230 and the sum of the age distribution. This missing data was considered during the statistical analysis to ensure an accurate and reliable interpretation of the results.

Table 1
Respondents' Demographic Information

Category	Subcategory	Percentage	Number of Teachers
School Type	Primary school only	53	122
	Secondary school only	40	92
	Both primary and secondary school	7	16
Educational Qualification	University degree in physics teaching (or combined with another subject)	81	187
	Degree in physics/astrophysics/biophysics/computer physics with additional pedagogical training	10	24
	Degrees in other fields with added pedagogical competencies	6	13
	Master's degree or doctorate in physics, educational physics, or didactics	3	6
Age Distribution	Under 25	1	3
	25–34	17	39
	35–45	34	78
	46–54	33	76
	55 or older	14	32
	No response	—	2
Work Experience	Less than 1 year	1	3
	1–5 years	14	33
	6–10 years	14	31
	11–15 years	19	44
	More than 15 years	52	119

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Participation in the survey was voluntary and anonymous, with respondents providing informed consent for their data to be used for research purposes. The study was conducted in compliance with the Declaration of Helsinki and was approved by the Ethics Committee of the University of Split, Faculty of Science (CLASS: 042-01/24-01/00020, NUMBER: 2181-204-02-07-24-00004, 8 July 2024).

Instrument and Procedures

The data for this study have been collected using an online questionnaire designed and administered via Google Docs. The development of the questionnaire has followed a rigorous two-phase process to ensure its relevance and reliability. In the first phase, a qualitative study has been conducted, consisting of semi-structured interviews with five primary school teachers and five secondary school teachers, selected through conventional sampling (Bornstein et al., 2013). These interviews have been conducted via video conference, phone, or in person. The primary aim of this phase was to identify relevant themes and questions that would inform the design of the quantitative portion of the research. Insights from these interviews have provided a foundation for the structure and content of the online questionnaire.

The final form of the questionnaire includes an introductory section, followed by three main sections to capture a comprehensive range of data. In the introductory section, respondents were informed about the survey's objectives and assured that the collected data would remain confidential and anonymous, with findings used solely for research purposes.

The first section of the questionnaire collects demographic information and preliminary opinions about gamification. It comprises questions regarding gender, age, work experience, the type of school where respondents work (primary or secondary), and their academic qualifications. Additionally, this section includes an open-ended question designed to explore the respondents' understanding of gamification. Respondents are presented with four options for defining gamification but also have the opportunity to articulate their own definition if none of the provided options align with their views.

The second section of the questionnaire focuses on teachers' knowledge and beliefs about gamification in physics education through 16 Likert-type items. These items address various aspects of gamification and its application, with responses recorded on a five-point scale ranging from 'strongly disagree' to 'strongly agree'. This section aims to capture quantitative data regarding teachers' familiarity with gamification and their beliefs on its effectiveness.

The third section of the questionnaire incorporates three open-ended questions designed to gather qualitative insights into teachers' knowledge and beliefs about gamification. These questions ask respondents to identify key elements of gamification they consider most effective in the physics classroom, technological tools or applications they deem useful for supporting gamification, and the specific challenges they perceive as common in implementing gamification in physics education. This section also allows respondents to share detailed and nuanced viewpoints that are not captured in the previous sections of the questionnaire.

The questionnaire is distributed to all physics teachers in Croatia via their official school email addresses, which school principals provide. The instrument remains open from February 1, 2024, to May 1, 2024. In mid-March, a reminder email is sent to encourage additional participation. This approach ensures that all teachers in the population have an equal opportunity to participate in the study, maximizing inclusivity and representativeness.

Several measures have been taken to ensure the validity and reliability of the questionnaire. The semi-structured interviews in the qualitative phase have ensured content validity by directly identifying key aspects of gamification from educators. The initial questionnaire version has been pilot tested with a small group of physics teachers who are not part of the main study. This has helped refine the items and eliminate any ambiguities. A Cronbach's alpha coefficient has also been calculated for the Likert-type items to assess internal consistency, with results indicating satisfactory reliability ().

This methodical approach ensures that the questionnaire is reliable and valid, providing a robust tool for exploring physics teachers' knowledge, beliefs and practices regarding gamification. By combining qualitative and quantitative methods, the study gains a comprehensive understanding of the topic while ensuring the psychometric soundness of the instrument (Cohen et al., 2002). The questionnaire is available in the repository at the following link: https://bit.ly/Anketa_igrifikacija.

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Data Analysis

The data collected in Google Forms have been imported and analyzed in the IBM SPSS 26 software package (Pallant, 2020). Different types of statistical analysis have been used, including also t-tests, ANOVA, and regression analysis.

A principal component factor analysis using Varimax rotation has been conducted to ascertain the scales' factor structure on teachers' knowledge and beliefs toward gamification in physics education (Table 2). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was KMO = 0.902, indicating excellent suitability for factor analysis. Bartlett's Test of Sphericity was significant, $\chi^2(120) = 2446.318$, $p < .001$, suggesting that the correlation matrix was not an identity matrix and that factor analysis was appropriate. The factor analysis has shown that two factors explain 63% of the variation, according to the Scree plot criterion and the Kaiser-Guttman criterion (eigenvalues greater than 1).

Table 2
The Scales' Factor Structure on Teachers' Knowledge and Beliefs Toward Gamification in Physics Education

Item	Knowledge	Beliefs
1. I am familiar with the different elements of gamification that can be used in physics lessons.	.817	
2. I have a good understanding of the concept of gamification in the context of physics lessons.	.809	
3. I frequently participate in training courses on the use of gamification in physics lessons.	.731	
4. I often use rewards or points as part of a gamification approach in physics lessons.	.767	
5. I frequently incorporate competitive elements or team dynamics as part of gamification in physics lessons.	.746	
6. I regularly adapt gamification activities to the different levels of knowledge of my students.	.704	
7. I make extensive use of technological tools or applications as part of gamification in physics lessons.	.686	
8. I believe that gamification promotes students' motivation during physics lessons.		.851
9. I believe that gamification encourages collaboration between students in physics lessons.		.844
10.I find that gamification sparks students' interest in the further study of physics concepts.		.842
11. I believe that gamification encourages students to ask more questions and seek further explanations of physics concepts.		.810
12. I think gamification helps to promote students' understanding of physical concepts.		.801
13. I believe that gamification improves the acquisition of practical skills in the field of physics.		.789
14. I observe that students react positively to the introduction of gamification activities in class.		.780
15. I believe that gamification encourages students' independence in physics research outside the classroom.		.774
16. I believe my knowledge of gamification significantly influences the successful application of this method in physics lessons.		.534
Characteristic root	32.819	7.211
% of variance	17.62	62.69
Cronbach alpha	.884	.928

The Kolmogorov-Smirnov test has been applied to assess the normality of distributions, and skewness and kurtosis values have been evaluated. Pearson's correlation coefficient has been employed to examine the association among the variables.

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Research Results

Table 3 presents the results of the descriptive analysis of both scales (knowledge and beliefs). The data indicate that teachers have knowledge of gamification since, on average, they assess the statements neutrally. However, they believe that gamification contributes or could contribute to increasing motivation and collaboration, thereby improving the educational outcomes in physics lessons. The variable distributions greatly diverge from the normal distribution. Therefore, the kurtosis and skewness of the distributions, whose recommended values range between -1 and 1, have been examined. Since all variables meet this criterion, it is concluded that parametric statistics methods can be applied to further data processing (Hair et al., 1998). The p-value represents the probability of observing the given data or something more extreme, assuming the null hypothesis is true. This value is used to determine statistical significance, with a threshold (commonly .05) indicating whether the results are unlikely to have occurred by chance.

Table 3
Results of the Descriptive Analysis of Both Scales: Knowledge and Beliefs About Gamification

Scale	Min	Max	*M*	*SD*	*Z*	*p*	Skewness	Kurtosis
Knowledge	1.00	5.00	2.71	0.83	.062	.032	0.067	0.192
Beliefs	1.00	5.00	3.48	0.71	.067	.015	0.611	0.973

Note. M = Mean; *SD* = Standard Deviation; I = Kolmogorov-Smirnov test statistic; *p* = Significance level. Skewness and Kurtosis describe the distribution shape. A significance level (p) below .05 suggests a deviation from normality.

To test whether younger teachers' knowledge and beliefs about gamification are statistically significantly higher than those of older teachers and whether gender, professional experience and school type play a statistically significant role in their knowledge and beliefs about this strategy, a one-way analysis of variance (ANOVA) has been conducted. The requirements for conducting an ANOVA are as follows: the dependent variable must be continuous, the variables must be normally distributed, there must be no extreme results, and sphericity must be met. The analysis is not highly sensitive to violating the normality assumption, especially if the groups comprise 100-200 or more respondents (Tabachnick & Fidell, 2007). However, the results may be unreliable if the variances are not homogeneous; therefore, Levene's test has been conducted, which has not been significant.

Table 4 represents the data from the descriptive analysis for each of the 16 Likert-type items on the number of respondents, mean score and standard deviation (Brooks et al., 2019).

Table 4
Results of the Descriptive Analysis of 16 Likert-type Items from the Online Gamification Questionnaire Provided by Physics Teachers in Croatia

Scale	Item	*N*	Min	Max	*M*	*SD*
Knowledge	1	230	1	5	2.77	0.992
	2	230	1	5	2.72	0.958
	3	230	1	5	2.32	1.106
	4	230	1	5	2.65	1.130
	5	230	1	5	2.74	1.049
	6	230	1	5	3.36	0.913
	7	230	1	5	3.61	0.931

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Scale	Item	N	Min	Max	M	SD
Beliefs	8	230	1	5	3.76	0.891
	9	230	1	5	3.58	1.037
	10	230	1	5	3.77	0.867
	11	230	1	5	3.06	1.018
	12	230	1	5	3.43	0.921
	13	230	1	5	2.70	0.998
	14	230	1	5	3.38	0.926
	15	230	1	5	3.31	0.965
	16	230	1	5	3.37	0.904

Note. Min = Minimum; *Max* = Maximum; *M* = Mean; *SD* = Standard Deviation. Responses were collected from 230 participants. Items 1–7 measure knowledge, while items 8–16 measure beliefs. The Likert scale ranged from 1 (Strongly Disagree) to 5 (Strongly Agree).

The responses to the statements regarding knowledge and beliefs about gamification have been measured on a 5-point Likert scale, with scores ranging from 2.32 (item 3) to 3.61 (item 7) for knowledge and 2.70 (item 13) to 3.77 (item 10) for beliefs.

For item 3, "I frequently participate in training courses on the use of gamification in physics lessons," the average score is the lowest – 2.32. This suggests that, on average, teachers do not frequently engage in training courses related to gamification. This lower score indicates a potential gap in professional development, implying that physics teachers may lack the readiness or training necessary to effectively apply gamification techniques in their teaching. In contrast, for item 7, "I make extensive use of technological tools or applications as part of gamification in physics lessons," the average score is the highest – 3.61. This suggests that, on average, teachers are more likely to incorporate technological tools and applications into their physics lessons as part of gamification, indicating a relatively higher level of engagement with technology-driven gamified teaching methods.

For item 13, "I believe that gamification improves the acquisition of practical skills in the field of physics," the average score was the lowest among the belief items – 2.70. This score is closer to the neutral midpoint (3), indicating that teachers are somewhat uncertain or less convinced about gamification's effectiveness in improving practical physics skills. This suggests that, while gamification may be seen as effective in sparking student interest, its impact on developing practical skills is viewed with less confidence. On the other hand, for item 10, "I find that gamification sparks students' interest in the further study of physics concepts," the average score was the highest among belief items – 3.77. This relatively high score suggests that teachers generally believe gamification plays a significant role in sparking students' interest in further studying physics concepts. It indicates that teachers view gamification as an engaging tool that enhances students' curiosity and motivation. Additionally, item 8, "I believe that gamification promotes students' motivation during physics lessons," scores highly, with an average of 3.76, reflecting optimism about the potential benefits of gamification in the classroom as well.

To examine whether statistically significant differences exist in each Likert-type item according to gender, age, work experience and school type, the Independent-Samples t-test and One-Way ANOVA have been conducted (Table 5).

Table 5
Independent-Samples t-Test and One-Way ANOVA for Differences in Gamification Score

Item	Gender	Age	Work Experience	School Type
1	.790	.606	.994	.282
2	.789	.561	.897	.095
3	.935	.945	.424	.244
4	.332	.461	.634	.721
5	.353	.184	.575	.291

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Item	Gender	Age	Work Experience	School Type
6	.140	.104	.086	.064
7	.383	.149	.059	.604
8	.576	.374	.284	.209
9	.464	.133	.066	.410
10	.326	.046	.031	.786
11	.290	.011	.023	.944
12	.327	.010	.001	.280
13	.327	.386	.041	.357
14	.738	.398	.054	.555
15	.471	.946	.161	.212
16	.624	.302	.011	.556

Note. This table presents the results of the independent-samples t-test and one-way ANOVA examining statistically significant differences in Likert-type item scores on gamification among Croatian physics teachers. The analysis was conducted based on gender, age, work experience, and school type. The presented values are p-values indicating the statistical significance of the differences.

The independent-samples t-test and one-way ANOVA results indicate that demographic factors such as gender, age, work experience, and school type generally do not significantly influence responses to most items, as most p-values exceed the .05 significance threshold. However, age has shown a significant effect on items 10 (p = .046), 11 (p = .011), and 12 (p = .010), suggesting that age may influence beliefs related to these items. Experience has significantly affected items 10 (p = .031), 11 (p = .023), 12 (p = .001), and 16 (p = .011), highlighting the influence of professional background on these specific aspects. School type and gender do not significantly affect any item, indicating a limited influence of these factors in this analysis.

To examine whether statistically significant differences exist in the knowledge and beliefs scales about gamification as a teaching strategy in physics classrooms in relation to gender, age, work experience, and school type, a one-way analysis of variance with repeated measures ANOVA has been conducted (Table 6). Statistically significant differences in beliefs about gamification have been identified within groups with varying levels of work experience.

Table 6
One-Way ANOVA of Teachers' Knowledge and Beliefs About Gamification

Scale	A Source of Variability	*SS*	*df*	*MS*	*F*	*p*
Knowledge	Gender	.241	1	.241	.369	.544
	Age	.650	1	.650	.998	.319
	Work Experience	.420	1	.420	.642	.423
	School Type	2.467	2	1.234	1.909	.151
Beliefs	Gender	.503	1	.503	.921	.338
	Age	2.005	1	2.005	3.718	.055
	Work Experience	3.594	1	3.594	6.749	.010
	School Type	1.303	2	.652	1.196	.304

Note. This table presents the results of the one-way ANOVA analyzing Croatian physics teachers' knowledge and beliefs about gamification. The analysis was conducted based on gender, age, work experience, and school type. SS = Sum of Squares; df = Degrees of Freedom; MS = Mean Squares; F = F - ratio (ratio of variance); p = Significance Level. Statistically significant results are in bold ($p < .05$).

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For the knowledge about the gamification scale, the findings indicate that none of the demographic variables significantly influence Croatian physics teachers' knowledge levels. Specifically, the p-values for gender (p = .544), age (p = .319), work experience (p = .423), and school range (p = .151) all exceed the significance threshold of .05. In contrast, the beliefs about gamification scale presented a more nuanced picture. While gender (p = .338) and school range (p = .304) do not show significant effects, age (p = .055) approached the significance threshold, indicating a potential trend worth further exploration. Work experience has emerged as a significant factor influencing beliefs about gamification, with a p-value of .010.

A series of linear regression analyses have been conducted to examine the relationship between knowledge about gamification and physics teachers' beliefs about this strategy. The predictor variables include gender, work experience, school and age (control variables), while the criterion variables are knowledge about gamification and teachers' beliefs. The necessary assumptions have been checked to carry out the regression analysis, including multicollinearity and the absence of autocorrelation of the residuals. In no case is the tolerance coefficient lower than .01, and the variance inflation factor (VIF) value does not exceed 10. The Durbin-Watson test result is satisfactory, with a value of 2.001. The results of the series of linear regression analyses are presented in Table 7.

Table 7

Linear Regression for Scales Knowledge and Beliefs About Gamification

Scale	A source of variability	*SS*	*df*	*MS*	*F*	*p*
Knowledge	Age/School Type	2.938	2	1.469	2.281	.105
	Age/Gender	0.083	2	0.415	0.635	.531
	Age/Work Experience	0.691	2	0.345	0.528	.591
	Gender/School Type	2.605	2	1.303	2.017	.135
	Gender/ Work Experience	0.570	2	0.285	0.436	.647
	Work Experience/School Type	2.678	2	1.339	2.075	.128
Beliefs	Age/School Type	2.239	2	1.119	2.070	.129
	Age/Gender	2.696	2	1.348	2.502	.084
	Age/Work Experience	3.709	2	1.855	3.471	.033
	Gender/School Type	0.899	2	0.449	0.822	.441
	Gender/ Work Experience	4.679	2	2.339	4.414	.013
	Work Experience/School Type	3.732	2	1.886	3.393	.032

Note. This table presents the results of the linear regression analysis of physics teachers' knowledge and beliefs about gamification. The model includes a combination of two predictor variables selected from gender, work experience, school type, and age. *SS* = Sum of Squares; *df* = Degrees of Freedom; *MS* = Mean Squares; *F* = F - ratio (ratio of variance); *p* = Significance Level. Statistically significant results are in bold ($p < .05$).

The findings reveal that demographic variables do not have a statistically significant influence on teachers' knowledge about gamification. For instance, the interactions between age and school type (p = .105), age and gender (p = .531), age and work experience (p = .591), gender and school type (p = .135), gender and work experience (p = .647), and work experience and school type (p = .128) produced p-values that were greater than the significance threshold of .05. In contrast to knowledge, beliefs about gamification are significantly influenced by specific combinations of demographic variables. The interaction between age and work experience (p = .033) suggests that these factors collectively shape teachers' beliefs toward gamification. Similarly, the combination of gender and work experience had a significant effect (p = .013), highlighting that gender, in conjunction with work experience, plays a role in shaping beliefs. The interaction between work experience and school type is also significant (p = .032), indicating that teachers' work environment, when combined with their work experience, affects their beliefs about gamification.

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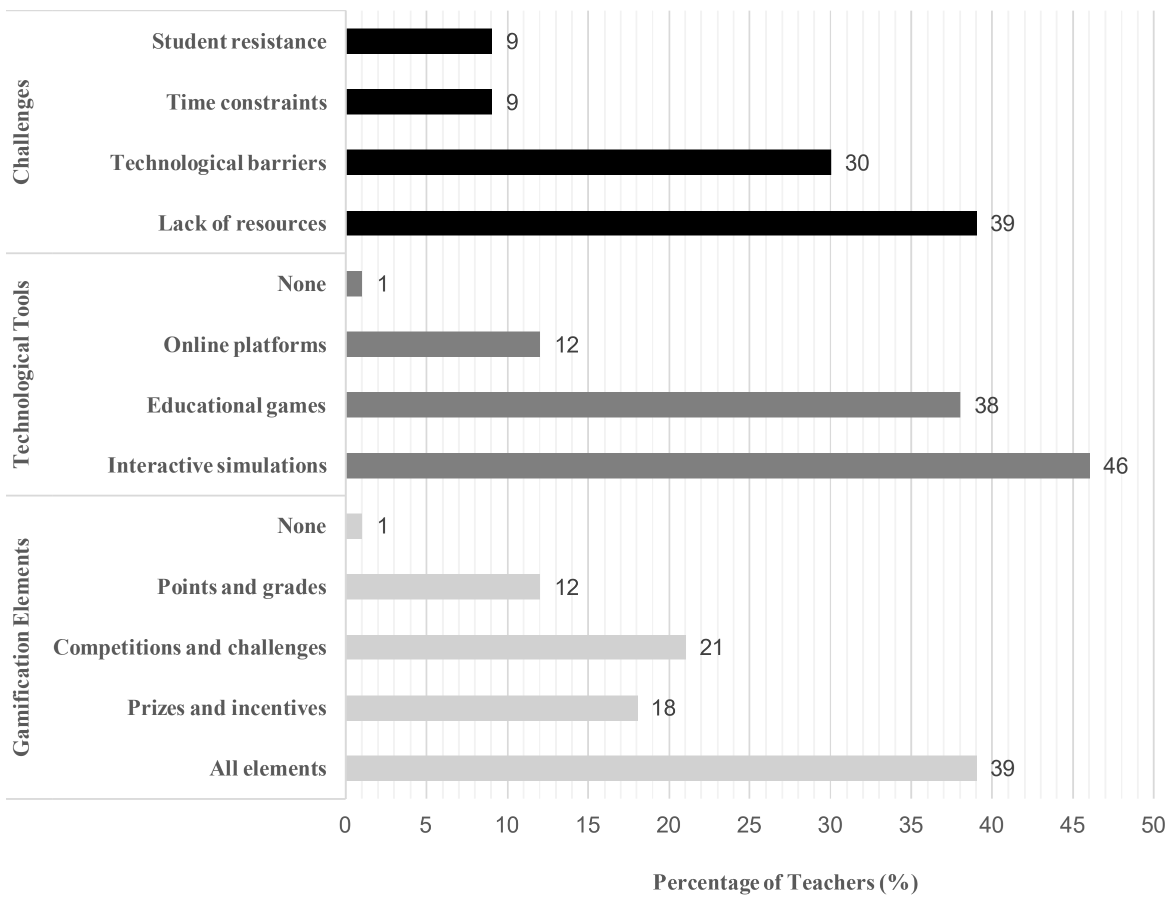
The following results focus on the three questions from the third part of the questionnaire. Responses provide insights into the key elements, technological tools, and challenges related to gamification in physics education, as perceived by Croatian teachers.

Teachers most commonly use competitions, challenges, prizes, and incentives as gamification elements, while a small percentage do not incorporate any (see Figure 1). The most frequently used technological tools are interactive simulations and educational games, though some teachers report not using any (see Figure 1). The main challenges include a lack of resources and technological barriers, with additional concerns about time constraints and student resistance (see Figure 1). Teachers also emphasize the effort required for lesson preparation in gamified environments, with several responses indicating the need for prepared materials, manuals, and training to implement gamification strategies effectively. The remaining percentage of responses up to 100% is not displayed in the graph, as teachers provided varied answers when selecting the "Other" option.

Figure 1
Teachers' Use of Gamification: Elements, Technological Tools, and Challenges



Discussion

This study examines how physics teachers at the primary and secondary levels self-assess their knowledge and beliefs about gamification and the significant differences in knowledge and beliefs based on age, gender, work experience, and school type. It also explores the effective game elements, useful tools, and challenges that teachers identify in implementing gamification.

A total of 230 physics teachers participated in the survey, representing 25% of Croatia's total population of physics teachers. The results indicate that, on average, physics teachers express neutral to moderately positive

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agreement in their evaluation of statements related to both their knowledge of gamification and their beliefs about its effects in the classroom.

The results have revealed no statistically significant differences in teachers' knowledge or beliefs about gamification based on gender. This finding suggests that pedagogical strategies like gamification are perceived similarly across genders, emphasizing its universal applicability in education. This result has aligned with previous studies, such as those by Mårell-Olsson (2019), Mårell-Olsson et al. (2015), and Mejtoft et al. (2017), who have highlighted gamification's potential to enhance student motivation and engagement, while also acknowledging that teachers often lack familiarity with its design and implementation.

Although age does not significantly influence teachers' knowledge of gamification, there is a trend toward significance in their beliefs, indicating that age might shape perceptions to some extent. This is consistent with findings by Brooks et al. (2019), who have observed that teachers' positive beliefs about gamification are influenced by its ease of use and the motivation it fosters in students, highlighting motivation as a key determinant of the effectiveness of this approach. This observation aligns with Kovalenko and Skvortsova (2022), who have reported that one in five teachers expressed negative attitudes toward certain gamification techniques, often due to difficulties in sustaining student engagement and ensuring the desired educational outcomes. Similarly, Brooks et al. (2019) have found a lack of gamification knowledge among teachers, which aligns with the current study's results on Croatian teachers.

Work experience, however, has been found to significantly impact teachers' beliefs, with more experienced teachers demonstrating stronger convictions about the value of gamification. This aligns with the findings of Sajinčič et al. (2022), who have noted that experienced teachers are more familiar with gamification and have had more opportunities to use it in their classrooms.

The analysis also indicates that the type of school (primary or secondary) does not have a significant effect on teachers' knowledge or beliefs about gamification. This might suggest a similar level of competence of physics teachers on gamification for primary and secondary schools. Mee Mee et al. (2020) have emphasized the importance of providing all teachers with appropriate materials and tools to support gamification, regardless of their school. This finding highlights the need for universally applicable strategies to address teachers' diverse needs in both primary and secondary education.

Regression analysis has explored the relationships between demographic factors and teachers' knowledge and beliefs about gamification. Although no significant predictors of knowledge have been identified from the demographic factors, both work experience and age have been found to have a significant influence on teachers' beliefs. Specifically, teachers with more experience tended to have stronger beliefs in the effectiveness of gamification. These results are consistent with those of Liu et al. (2023), who have reported that demographic factors such as gender, age, work experience, and school type did not significantly impact the effectiveness of gamification but have noted that experience influences teachers' beliefs toward its use. The finding that experience contributes to stronger beliefs about gamification underscores the importance of mentoring programs, where experienced teachers can share their expertise with less experienced colleagues.

Responses to the open-ended questions in the questionnaire provide additional insights. Teachers have identified rewards, competitive elements, and technological tools as the most effective game elements for physics education. Specifically, 39% of teachers have favored all proposed game elements, while 18% have highlighted prizes and incentives, 21% have emphasized competitions and challenges, and slightly more than 12% note points and grades. Only 1% of respondents have reported not using any game elements in their lessons. These findings indicate that while teachers recognize the potential of gamification to enhance engagement, its practical implementation varies widely.

Technological tools are a key focus, with 46% of teachers reporting the use of interactive simulations, 38% utilizing educational games, and 12% relying on online platforms to support gamification. These findings highlight the integration of gamification with digital resources as a prevalent teaching method. However, some teachers express concerns about the artificiality of simulations compared to real experiments, suggesting that hands-on activities may be more effective in deepening students' understanding of physics concepts. This has also been highlighted in a study on physics teaching in Croatia during the pandemic, where many physics teachers, despite the mentioned concerns, have adapted to the circumstances using various digital tools (Štibi et al., 2021).

In this study, teachers have also identified several challenges in implementing gamification. The most significant barrier was the lack of resources (39%), followed by technological challenges (30%), time constraints (9%), and student resistance (9%). The need for training and prepared materials is a recurring theme in teachers' responses, with many emphasizing the importance of accessible resources and instructional guides to facilitate gamifica-

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tion. For instance, one teacher noted, "It takes time and research, but it would be great if there were some kind of manual with helpful ideas and tips." These findings align with Barringer et al. (2018), who have emphasized that while gamification can enhance learning, it must be complemented by addressing students' alternative conceptions and incorporating iterative design improvements and reflective practices into gamified tools. Without these additional considerations, gamification risks being superficial and less effective in fostering deep conceptual understanding. Another teacher in our study pointed out the challenge of creating well-designed games tailored to physics education, noting, "There is a lack of consistently designed and tested games specifically for teaching physics, as well as insufficient technological support for dynamic, interactive input exchange in the classroom."

The findings from this study highlight that while many Croatian physics teachers recognize the potential of gamification to engage students, its success depends on thoughtful implementation and alignment with learning objectives. This aligns with Lampropoulos and Kinshuk (2024), who have reported that gamification demonstrates strong cognitive benefits, although its effects on motivation and behavior are less consistent. In addition, Fleissner-Martin et al. (2024) have emphasized the value of gamified strategies in cultivating essential skills such as creativity and critical thinking, underscoring the need for professional development to equip teachers with effective implementation strategies.

The results of this study also underscore the importance of addressing practical barriers to gamification, including the need for training, resources, and technological support. While gamification has significant potential to enhance student engagement and motivation, its success depends on equipping teachers with the necessary tools and knowledge to implement it effectively. Future research should focus on developing comprehensive training programs and resources tailored to the needs of physics teachers, enabling them to overcome these challenges and maximize the benefits of gamification.

Conclusions and Implications

The present study examines Croatian physics teachers' knowledge and beliefs about gamification. The findings indicate that while teachers acknowledge gamification's potential to engage students, they report limited participation in gamification training, pointing to a gap in professional development. Teachers are more comfortable using technological tools like interactive simulations and educational games but are less convinced of gamification's effectiveness in developing practical physics skills. Demographic factors like age and work experience significantly influenced teachers' beliefs, with older and more experienced teachers demonstrating stronger positive beliefs toward gamification. However, gender and school type do not significantly affect teachers' knowledge or beliefs.

Further findings indicate that teachers recognize various effective gamification elements, with prizes, competitions, and points frequently cited as key components. Regarding technological tools, most teachers reported using interactive simulations, educational games, and online platforms to support gamification. The study also identifies several significant challenges in implementing gamification, such as insufficient resources, technological barriers, time constraints, and student resistance. These challenges highlight the need for enhanced training, support, and resource availability to facilitate the integration of gamification into classrooms. Additionally, teachers emphasize the importance of practical guides and well-designed materials to support successful implementation.

Therefore, the implications of this research extend to both policy and practice. Educational institutions should invest in comprehensive training programs to improve teachers' knowledge of gamification and foster collaboration. Providing ready-to-use teaching materials and technological support can help teachers integrate gamification more easily. Mentorship between experienced and less experienced teachers will further strengthen its adoption.

Although the study provides valuable insights into gamification in physics education from the perspective of teachers, it also identifies areas for future research. The survey's brevity limits the depth of teachers' experiences, so future studies should incorporate qualitative approaches to explore how gamification impacts teaching and learning. Longitudinal studies are needed to assess the long-term effects of gamification on students' academic achievements, beliefs toward physics, and engagement. Research on its impact on diverse student populations, including those with special educational needs, would further enrich understanding.

The research presented here contributes to the growing body of knowledge on gamification and highlights its potential to make physics education more accessible and effective for diverse learners. Finally, the full potential of gamification as a pedagogical tool can be realized by overcoming challenges and harnessing teachers' positive beliefs. With the right support, gamification can transform physics classrooms into dynamic, engaging environments that foster curiosity, participation, and a deeper understanding of the subject.

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ISSN 2538–7138 /Online/

Declaration of Interest

The authors declare no competing interest.

References

Andrade, C. (2020). The limitations of online surveys. Indian Journal of Psychological Medicine, 42(6), 575–576. https://doi.org/10.1177/0253717620957496

Ary, D., Jacobs, L. C., & Razavieh, A. (1972). Introduction to research in education. Holt, Rinehart and Winston.

Asrizal, A., Annisa, N., Festiyed, F., Ashel, H., & Amnah, R. (2023). STEM-integrated physics digital teaching material to develop conceptual understanding and new literacy of students. Eurasia Journal of Mathematics, Science and Technology Education, 19(7), Article em2289. https://doi.org/10.29333/ejmste/13275

Bai, S., Hew, K. F., & Huang, B. (2020). Does gamification improve student learning outcomes? Evidence from a meta-analysis and synthesis of qualitative data in educational contexts. Educational Research Review, 30, Article 100322. https://doi.org/10.1016/j.edurev.2020.100322

Bao, L., & Koenig, K. (2019). Physics education research for 21st century learning. Disciplinary and Interdisciplinary Science Education Research, 1(1), Article 2. https://doi.org/10.1186/s43031-019-0007-8

Barringer, D. F., Plummer, J. D., Kregenow, J., & Palma, C. (2018). Gamified approach to teaching introductory astronomy online. Physical Review Physics Education Research, 14(1), Article 010140. https://doi.org/10.1103/PhysRevPhysEducRes.14.010140

Bellocchi, A., Mills, R., Arthars, N., Johnson, P., Smith, L., Brown, T., Davis, J., Evans, M., Garcia, S., & Thompson, R. (2024). Preservice science teachers' epistemic cognition during online searching. Research in Science Education, 54(1), 123–145. https://doi.org/10.1007/s11165-024-10214-0

Bornstein, M. H., Jager, J., & Putnick, D. L. (2013). Sampling in developmental science: Situations, shortcomings, solutions, and standards. Developmental Review, 33(4), 357–370. https://doi.org/10.1016/j.dr.2013.08.003

Brecl, J., Kordigel Aberšek, M., Čamplj, B., & Flogie, A. (2024). STEAM learning as a base for developing communication skills in inclusive schools. Journal of Baltic Science Education, 23(5), 854–866. https://doi.org/10.33225/jbse/24.23.854

Brooks, E., Gissurardottir, S., Jonsson, B. T., Kjartansdottir, S., Munkvold, R. I., Nordseth, H., & Sigurdardottir, H. I. (2019). What prevents teachers from using games and gamification tools in Nordic schools? In A. Brooks, E. Brooks, & N. Vidakis (Eds.), Interactivity, game creation, design, learning, and innovation: 7th EAI international conference, ArtsIT 2018, and 3rd EAI international conference, DLI 2018, ICTCC 2018, Braga, Portugal, October 24–26, 2018, Proceedings (Vol. 7, pp. 472–484). Springer. https://doi.org/10.1007/978-3-030-06134-0_50

Buckley, P., & Doyle, E. (2016). Gamification and student motivation. Interactive Learning Environments, 24(6), 1162–1175. https://doi.org/10.1080/10494820.2014.964263

Byun, T., & Lee, G. (2014). Why students still can't solve physics problems after solving over 2000 problems. American Journal of Physics, 82(9), 906–913. https://doi.org/10.1119/1.4881606

Cayless, A., & Jordan, S. (2024). The challenges of physics education in the digital era. In C. Hidalgo (Ed.), EPS Grand Challenges: Physics for Society in the Horizon 2050 (pp. 8-10–8-14). IOP Publishing. https://doi.org/10.1088/978-0-7503-6342-6ch8

Cohen, L., Manion, L., & Morrison, K. (2002). Research methods in education (6th ed.). Routledge. https://doi.org/10.4324/9780203224342

Creswell, J. W., & Guetterman, T. C. (2019). Educational research: Planning, conducting, and evaluating quantitative and qualitative research (6th ed.). Pearson.

Ćosić, A. (2015). Analiza stavova učenika osječkih srednjih škola o nastavi fizike i informatike [Analysis of the attitudes of Osijek high school students towards physics and informatics teaching] (Diplomski rad). Sveučilište Josipa Jurja Strossmayera u Osijeku, Odjel za fiziku. https://urn.nsk.hr/urn:nbn:hr:160:554320

Deterding, S., Sicart, M., Nacke, L., O'Hara, K., & Dixon, D. (2011). Gamification: Using game-design elements in non-gaming contexts. In CHI'11 Extended Abstracts on Human Factors in Computing Systems (pp. 2425–2428). Association for Computing Machinery.

DeWitt, P. M. (2016). Collaborative leadership: Six influences that matter most. Corwin Press.

Dichev, C., & Dicheva, D. (2017). Gamifying education: What is known, what is believed, and what remains uncertain: A critical review. International Journal of Educational Technology in Higher Education, 14, Article 9. https://doi.org/10.1186/s41239-017-0042-5

Dziob, D. (2020). Board game in physics classes—A proposal for a new method of student assessment. Research in Science Education, 50(4), 845–862. https://doi.org/10.1007/s11165-018-9714-y

Erceg, N., Jelovica, L., Mešić, V., Nešić, L., Poljančić Beljan, I., & Nikolaus, P. (2023). Causes of the shortage of physics teachers in Croatia. Education Sciences, 13(8), Article 788. https://doi.org/10.3390/educsci13080788

Fleissner-Martin, J., Paul, J., & Bogner, F. X. (2024). Creativity as key trigger to cognitive achievement: Effects of digital and analog learning interventions. Research in Science Education. Advance online publication. https://doi.org/10.1007/s11165-024-10211-3

Forndran, F., & Zacharias, C. R. (2019). Gamified experimental physics classes: A promising active learning methodology for higher education. European Journal of Physics, 40(4), Article 045702. https://doi.org/10.1088/1361-6404/ab215e

Hair, J. F., Jr., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (1998). Multivariate data analysis (5th ed.). Prentice Hall.

Hidalgo, C., & Lee, D. (2022). Introduction: Grand challenges for physics. Europhysics News, 53(5), 15–16.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Hidalgo, C., Rossel, C., Lee, D., Sakellariadou, M., Wulz, C.-E., van der Beek, K., Ritort, F., Van Tiggelen, B., Assmann, R., Cerullo, G., Cifarelli, L., Barbato, F., Beck, C., & van Dyck, L. (Eds.). (2024). EPS grand challenges: Physics for society in the horizon 2050. IOP Publishing. https://doi.org/10.1088/978-0-7503-6342-6

Jantakoon, T., Jantakun, K., Jantakun, T., Trisupakitti, S., & Limpinan, P. (2024). STEAM education with gamification: A bibliometric analysis. Higher Education Studies, 14(3), 90–102. https://doi.org/10.5539/hes.v14n3p90

Johnson, R. B., & Christensen, L. (2019). Educational research: Quantitative, qualitative, and mixed approaches. Sage Publications.

Jugović, I. (2010). Uloga motivacije i rodnih stereotipa u objašnjenju namjere odabira studija u stereotipno muškom području [The role of motivation and gender stereotypes in explaining the intention to choose a study in a stereotypically male field]. Sociologija i prostor: časopis za istraživanje prostornoga i sociokulturnog razvoja, 48(1 (186)), 77–98.

Kam, A., & Umar, I. (2023). Would gamification affect high and low achievers differently? A study on the moderating effects of academic achievement level. Education and Information Technologies, 28(5), 8075–8095. https://doi.org/10.1007/s10639-022-11519-1

Ketelhut, D. J., & Schifter, C. C. (2011). Teachers and game-based learning: Improving understanding of how to increase efficacy of adoption. Computers & Education, 56(2), 539–546. https://doi.org/10.1016/j.compedu.2010.10.002

Kontorovich, I., & Koichu, B. (2016). A case study of an expert problem poser for mathematics competitions. International Journal of Science and Mathematics Education, 14, 81–99. https://doi.org/10.1007/s10763-013-9467-z

Kovalenko, I. V., & Skvortsova, T. P. (2022). Game technologies and gamification techniques in teaching English: An analysis of pedagogical experience. RUDN Journal of Psychology and Pedagogics, 19(2), 382–392. https://doi.org/10.22363/2313-1683-2022-19-2-382-392

Lampropoulos, G., & Kinshuk. (2024). Virtual reality and gamification in education: A systematic review. Educational Technology Research and Development, 72(6), 1691–1785. https://doi.org/10.1007/s11423-024-10351-3

Liu, T., Oubibi, M., Zhou, Y., & Fute, A. (2023). Research on online teachers' training based on the gamification design: A survey analysis of primary and secondary school teachers. Heliyon, 9(4), Article e15053. https://doi.org/10.1016/j.heliyon.2023.e15053

López, P., Rodrigues-Silva, J., & Alsina, Á. (2021). Brazilian and Spanish mathematics teachers' predispositions towards gamification in STEAM education. Education Sciences, 11(10), Article 618. https://www.mdpi.com/2227-7102/11/10/618

Mårell-Olsson, E. (2019). University students as co-creators in designing gamification teaching activities using emergent technologies in Swedish K-12 education. IxD&A: Interaction Design and Architecture(s), (42), 47–69. https://doi.org/10.55612/s-5002-042-003

Mårell-Olsson, E., Mejtoft, T., & Jahnke, I. (2015). Designing for collaborative learning expeditions by using wearable technology and smart glasses. In O. Lindwall, P. Hakkinen, T. Koschmann, P. Tchounikine, & S. Ludvigsen (Eds.), Exploring the material conditions of learning: Proceedings of the 11th international conference on computer supported collaborative learning (Vol. 2, pp. 689–690). The International Society of the Learning Sciences.

Marušić, M., & Sliško, J. (2009). Postoje li „muški" i „ženski" stavovi o učenju fizike, o fizici kao znanosti i fizici kao struci? [Are there "male" and "female" attitudes towards learning physics, physics as a science, and physics as a profession?]. Metodički ogledi: Časopis za filozofiju odgoja, 16(1–2), 87–111.

McDermott, L. C., & Redish, E. F. (1999). Resource letter: PER-1: Physics education research. American Journal of Physics, 67(9), 755–767. https://doi.org/10.1119/1.19122

McGonigall, J. (2010, February). Gaming can make a better world [Video]. TED Conferences. https://www.ted.com/talks/jane_mcgonigal_gaming_can_make_a_better_world

McLoughlin, E., Butler, D., Kaya, S., & Costello, E. (2020). STEM education in schools: What can we learn from the research? ATS STEM Report #1. Dublin City University. https://doi.org/10.5281/zenodo.3673728

Mee Mee, R. W., Shahdan, T. S. T., Ismail, M. R., Ghani, K. A., Pek, L. S., Von, W. Y., Woo, A., & Rao, Y. S. (2020). Role of gamification in classroom teaching: Pre-service teachers' view. International Journal of Evaluation and Research in Education, 9(3), 684–690. https://doi.org/10.11591/ijere.v9i3.20622

Mejtoft, T., Lindberg, L., Söderström, U., & Mårell-Olsson, E. (2017). Feedback in commercial educational applications: Guidelines and conceptual framework. Proceedings of the European Conference on Cognitive Ergonomics (ECCE 2017),(pp.113–120). ACM Digital Library. https://doi.org/10.1145/3121283.3121296

Mukh, Y. A., Tarteer, S., AL-Qasim, M., Saqer, K., & Daher, W. (2023). Using gamification to motivate students with simple-moderate intellectual disabilities. European Journal of Educational Research, 12(2), 639–647. https://doi.org/10.12973/eu-jer.12.2.639

Musyaffi, A. M., Sulistyowati, W. A., Wolor, C. W., & Sasmi, A. A. (2022). Game-based learning sustainability during social distance: The role of gamification quality. European Journal of Educational Research, 11(3), 1289–1302. https://doi.org/10.12973/eu-jer.11.3.1289

MZO. (2024a). Osnovne škole [Primary schools]. Ministarstvo znanosti i obrazovanja Republike Hrvatske. http://mzos.hr/dbApp/pregled.aspx?appName=OS

MZO. (2024b). Srednje škole [Secondary schools]. Ministarstvo znanosti i obrazovanja Republike Hrvatske. http://mzos.hr/dbApp/pregled.aspx?appName=SS

Novak, J. D., & Gowin, D. B. (1984). Learning how to learn. Cambridge University Press. https://doi.org/10.1017/CBO9781139173469

Pallant, J. (2020). SPSS survival manual: A step by step guide to data analysis using IBM SPSS (7th ed.). Routledge. https://doi.org/10.4324/9781003117452

Paľová, D., & Vejačka, M. (2022). Implementation of gamification principles into higher education. European Journal of Educational Research, 11(2), 763–779. https://doi.org/10.12973/eu-jer.11.2.763

Perera, V. H., & Hervás-Gómez, C. (2021). University students' perceptions toward the use of an online student response system in game-based learning experiences with mobile technology. European Journal of Educational Research, 10(2), 1009–1022. https://doi.org/10.12973/eu-jer.10.2.1009

https://doi.org/10.33225/jbse/25.24.255

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Rusevska, K., Barandovski, L., Petruševski, V., Naumoska, A., Tofilovska, S., & Stojanovska, M. (2024). Innovative learning activities for ethnically diverse students in Macedonian science education. Center for Educational Policy Studies Journal, 14(1), 55–77. https://doi.org/10.26529/cepsj.1692

Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. Educational Psychology Review, 32(1), 77–112. https://doi.org/10.1007/s10648-019-09498-w

Sajinčič, N., Sandak, A., & Istenič, A. (2022). Pre-service and in-service teachers' views on gamification. International Journal of Emerging Technologies in Learning (iJET), 17(3), 83–103. https://doi.org/10.3991/ijet.v17i03.26761

Simel, S. (2016). Boris Jokić: Science and religion in Croatian elementary education: Pupils' attitudes and perspectives. Sociologija i prostor: časopis za istraživanje prostornoga i sociokulturnog razvoja, 54(2 (205)), 189–193. https://doi.org/10.5673/sip.55.2.6

Soboleva, E. V., Galimova, E. G., Maydangalieva, Z. A., & Batchayeva, K. K.-M. (2018). Didactic value of gamification tools for teaching modeling as a method of learning and cognitive activity at school. Eurasia Journal of Mathematics, Science and Technology Education, 14(6), 2427–2444. https://doi.org/10.29333/ejmste/89843

Song, D., Tavares, A., Pinto, S., & Xu, H. (2017). Setting engineering students up for success in the 21st century: Integrating gamification and crowdsourcing into a CDIO-based web design course. Eurasia Journal of Mathematics, Science and Technology Education, 13(7), 3565–3585. https://doi.org/10.12973/eurasia.2017.00745a

Su, C.-H. (2019). The effect of users' behavioral intention on gamification augmented reality in STEM (GAR-STEM) education. Journal of Baltic Science Education, 18(3), 450–465. https://doi.org/10.33225/jbse/19.18.450

Susman, K., & Pavlin, J. (2020). Improvements in teachers' knowledge and understanding of basic astronomy concepts through didactic games. Journal of Baltic Science Education, 19(6), 1020–1033. https://doi.org/10.33225/jbse/20.19.1020

Swacha, J. (2021). State of research on gamification in education: A bibliometric survey. Education Sciences, 11(2), Article 69. https://doi.org/10.3390/educsci11020069

Štibi, I., Čepič, M., & Pavlin, J. (2021). Physics teaching in Croatian elementary and high schools during the Covid-19 pandemic . Center for Educational Policy Studies Journal, 11(Sp.Issue), 335–360. https://doi.org/10.26529/cepsj.1135

Tabachnick, B. G., & Fidell, L. S. (2007). Experimental designs using ANOVA (Vol. 724). Thomson/Brooks/Cole.

TERC. (2020). Games. TERC. https://www.terc.edu

Thoms, L.-J., Becker, S., & Kremser, E. (2023). Teaching and learning physics with digital technologies—What digitalization-related competencies are needed? In M. Streit-Bianchi, M. Michelini, W. Bonivento, & M. Tuveri (Eds.), New challenges and opportunities in physics education (pp. 313–326). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-37387-9_21

Vieyra, R., Vieyra, C., Pendrill, A.-M., & Xu, B. (2020). Gamified physics challenges for teachers and the public. Physics Education, 55(4), Article 045014. https://doi.org/10.1088/1361-6552/ab8779

Walraven, A., Brand-Gruwel, S., & Boshuizen, H. P. A. (2009). How students evaluate information and sources when searching the World Wide Web for information. Computers & Education, 52(1), 234–246. https://doi.org/10.1016/j.compedu.2008.08.003

Zvarych, I., Kalaur, S. M., Prymachenko, N. M., Romashchenko, I. V., & Romanyshyna, O. I. (2019). Gamification as a tool for stimulating the educational activity of students of higher educational institutions of Ukraine and the United States. European Journal of Educational Research, 8(3), 875–891. https://doi.org/10.12973/eu-jer.8.3.875

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THE IMPACT OF SCENARIO-BASED LEARNING ON THE SCIENTIFIC CREATIVITY AND REFLECTIVE THINKING SKILLS OF FOURTH-GRADE STUDENTS IN PRIMARY SCHOOL

Tekin Guler

Abstract. *The current study examines the impacts of scenario-based science activities on the scientific creativity and reflective thinking skills of fourth-grade students in primary school. Therefore, it was carried out in a primary school in Yozgat city center during the 2023-2024 Academic Year. An experimental group (24 students [13 girls, 11 boys]) and a control group (22 students [12 girls, 10 boys]) were formed from the fourth grade of the school in question. Science Scientific Creativity Questionnaire and Science Reflective Thinking Scale were utilized as data collection tools during the experimental process, which lasted ten weeks with three hours each week. The data obtained via the research were analyzed through independent samples t-tests along with dependent samples t-tests. The results obtained through the analysis exhibited a significant difference in the experimental group's favor with regard to understanding, reflection, and total score of reflective thinking in all sub-dimensions of scientific creativity. Based on these results, it is thought that using scenario-based learning activities would be beneficial in primary school science courses.*

Keywords: *primary school, reflective thinking, science education, scientific creativity*

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Introduction

Nowadays, the concept of science literacy has gained increasing importance in parallel with the changes in science and technology. Science literacy aims to develop the questioning, problem-solving, and decision-making skills of students and to enable them with the attitudes, knowledge, and skills required for lifelong learning (Roberts, 2007). Moreover, scientific literacy involves making decisions, using scientific knowledge, and drawing evidence-based conclusions in the process of interpreting the world and the changes made by people in this world (The Organization for Economic Cooperation and Development [OECD], 2006). Based on its increasing significance and the changes in science and technology, the concept of science literacy has entered into a process of evolution from Vision I to Vision III (Guler, 2024c; Roberts, 2007). Vision I highlights the product and process dimensions of science and focuses on teaching scientific knowledge, processes, and the relationships between them. Hence, students are expected to use the scientific concepts they learn in order to solve the individual, social, and cultural problems they encounter in their daily lives (Bybee, 2015; Guler, 2024c). On the other hand, in Vision II, the emphasis is first on creating contexts and then accessing scientific knowledge and processes so as to improve the decision-making skills of students on science-related issues (Guler, 2024c; Roberts, 2007). Vision III, therefore, stresses sustainability and value in science literacy, based on the prediction that society needs educated and critical-thinking individuals who can make science and value-based decisions about sustainability issues (Hodson, 2011; Sjöström, 2015). Next Generation Science Standards [NGSS] (2013) bears traces of these three visions of science literacy in terms of its applications and adoption of an interdisciplinary approach, which prioritizes scientific processes, connects with social and cultural problems, and emphasizes scientific communication and decision-making. A similar situation to this emphasis in NGSS (2013) is also included in the 2018 science

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curriculum in Türkiye, which bears traces of science literacy visions with the field of Knowledge, Skills, Sense and Science Technology-Society-Environment learning (Saglam et al., 2016). Briefly, this curriculum can be claimed to have a structure that synthesizes different visions of science literacy and to envisage specifically the use of teaching methods and techniques which enable students to participate in the process of learning actively, support thinking skills, and provide meaningful and permanent learning (Guler, 2024a; Guler, 2024c). One of the methods thought to be effective in gaining these competencies, which are necessary for reaching science literacy, is scenario-based learning. Scenario-based learning is an innovative education method which aims to equip students with knowledge and skills in a real-world context (Mariappan et al., 2004). This learning approach allows students to understand theoretical knowledge more profoundly by applying it in practice. Scenarios generally include situations where students are provided various problems, situations, or events and are expected to generate solutions in this context (Bayrak, 2010; Guler, 2024b; Mariappan et al., 2004). The success of scenario-based learning is dependent on designing scenarios which are realistic and appropriate to the level of students (Guler, 2024b). In this regard, well-designed scenarios enable students an opportunity to question their knowledge, acquire new information, and use this information in practice. In this way, students acquire not only theoretical knowledge but also learn how to utilize this knowledge (Cerrah-Ozsevgec & Kocadag, 2013). Scenario-based learning not only triggers the student to participate in the process actively but ensures that the student enjoys the process, as well (Guler, 2024b; Flynn & Klein, 2001; Razzouk, 2011). These features of scenario-based learning cause the use of this method at the primary school level to become more important. As children at the primary school level have difficulty in learning abstract subjects as a characteristic of their age and have difficulty in transferring the learned subjects into life (e.g., Akar & Yadigaroğlu, 2021), they get bored with the learning process quickly. Furthermore, in this period when attitudes towards science begin to form, loving science and feeling that being interested in science becomes enjoyable, affects the future lives of children directly. In this respect, it is a known fact that scenario-based learning influences attitudes toward science positively (Karaoglan, 2019; Kemiksiz, 2016; Ozturk & Karakas, 2023; Razzouk, 2011). In addition to these advantages of scenario-based learning, studies in the literature indicate that scenario-based learning affects students' academic success positively (Karaoglan, 2019; Ozkurt-Ozturk, 2019; Yıldız, 2022) and increases the permanence of what is learned (Ciraj et al., 2010; Ozkurt-Ozturk, 2019; Smith, 1987; Yıldız, 2022). In the previous literature, some studies exist, which suggest that it increases students' motivation (Karci, 2018), is effective in terms of eliminating misconceptions (Cerrah-Ozsevgec & Kocadag, 2013), and is effective in gaining scientific thinking habits (Avcı & Bayrak, 2013; Cakir & Kilcan, 2022; Siddiqui et al., 2008). When those advantages are considered, it is thought that using scenario-based learning at the primary school level will provide many advantages, such as making children love science and increasing their academic success in science classes. In spite of the advantages it will provide, limited studies on the use of scenario-based learning in primary school science teaching can be found in the literature (Karaoglan, 2019; Ozkurt-Ozturk, 2019; Yıldız, 2022). Similarly, there are limited studies on scientific creativity at the primary school level (Cremin et al., 2015; Cavusoglu, 2022; Jongluecha & Worapun, 2022) and reflective thinking (Altın & Saracaloğlu, 2018; Wendell et al., 2017), which are directly or indirectly among the 21st-century skills. These studies generally examine students' ability to present creative ideas, (Bhakti & Austiti, 2018; Cavusoglu, 2022), or aim to find out the impact of the intervention on creative thinking (Guler, 2024; Jongluecha & Worapun, 2022; McCormak, 1971), the effect of reflective thinking on decision-making processes of students (Wendell et al., 2017), and the effect of the intervention on reflective thinking (Atabas, 2020; Guler, 2024a; Kozikoglu & Tunc, 2020). These limitations in the literature on scenario-based learning, scientific creativity, and reflective thinking form the basis for the present study. This study is thought to contribute significantly to the literature by determining how the use of scenario-based learning in science classes at the primary school level influences the development of two important skills, such as scientific creativity and reflective thinking. Moreover, this study will encourage teachers to use scenario-based learning at the primary school level, and it will provide good examples for teachers to use. In this respect, this study has aimed to observe the impact of scenario-based learning on the scientific creativity and reflective thinking skills of fourth-grade students studying in a primary school. Bearing this in mind, the questions below have been intended to be answered;

1. How does the use of scenario-based learning activities in the fourth-grade primary school science course impact scientific creativity skills?
2. How does the use of scenario-based learning activities in the fourth-grade primary school science course impact reflective thinking skills?

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Research Methodology

General Background

The study employed a quasi-experimental design featuring a pre- and post-test control group. This non-randomized approach aims to control the effect of certain variables, despite not randomly assigning participants to experimental groups (Büyüköztürk, 2008). The current study was carried out with fourth-grade students in a public primary school in Yozgat, Türkiye. Two classes at the fourth-grade level in the school, possessing similar characteristics with regard to the number of students and gender distribution, were selected so as to form the experimental and control groups in the study. A simple random sampling method was utilized in order to ensure impartiality in creating the control and experimental groups (Büyüköztürk, 2008). Following the formation of groups, the scenarios that would be used in the teaching process in the experimental group were built by the researcher.

The Development of Scenarios

Within the scope of the study, scenario-based activities developed by the researcher were practiced with the students who were taking part in the experimental group. The phasing made by Harfler (1997) was utilized while creating these activities, and the process of building scenarios was as follows;

- Planning: At this stage, the fourth-grade science curriculum was examined, and all learning outcomes in the "Our Food" and "Human and Environment" units within the "Living Creatures and Life" subject area in the 2018 Science Curriculum were chosen as the scope for the scenarios to be prepared.
- Writing: At this stage, the selected topics and learning outcomes were grouped in order to create scenarios. While making this grouping, the aim was to make the scenarios appropriate for fourth-grade students and to increase active participation in the activities without getting bored throughout the process. Furthermore, care has been taken to ensure full coverage without ignoring any subject or achievement. Considering the age characteristics of fourth-grade students, it was thought that the use of fairy-tale characters would attract much attention, and in this regard, the characters in the scenario (king, queen, etc.) were created. However, scenarios were built by blending real-life situations with these fairy-tale characters due to the nature of scenario-based learning. A total of four different scenarios were built, and the scenarios were sent to three experts: a primary school teacher, a Turkish teacher, and an expert in the field of classroom education at university level, to ask for their opinions. Necessary corrections were made by taking the suggestions of experts, such as simplifying the language and shortening the script texts into account.
- Practice: The prepared scenarios were practiced with fourth-grade students studying in a primary school in the Çekerek district of Yozgat. During the practice process, the problems experienced by the teacher and the students were recorded by the primary school teacher and the researcher who was in the classroom as an observer. The records kept by the teacher were shared with the researcher at the end of each scenario.
- Correction: Following the interview with the primary school teacher after the practice and the observation made by the researcher during the practice, corrections that were deemed necessary were made including giving more clues within the problem so that the student could create a problem, reducing the number of characters in the scenario text, detailing the lesson plan for the teacher, etc. The scenarios were sent to three experts again, including a classroom teacher, a Turkish language teacher, and a Classroom Education expert at the university level, and the experts were asked for their opinions on the scenario. The process of building scenarios was finalized by implementing formal correction suggestions of the experts. An example of the scenarios utilized within the scope of the study is displayed in Figure 1.

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Picture 1
Example Scenario

Who will be The New Queen?

Once upon a time, there was a country where everyone lived in peace. The king was good to his people and tried to make their lives better. His country was facing problems. It is lovely but crowded, and has very limited energy resources.

This makes it hard to meet the country's electricity needs. People don't use electricity wisely. This meant too much electricity was used for lighting, so the country wasn't well enough lit in the evening. The king wanted to keep his people safe and healthy. He wanted the streets and avenues of his country to be brightly lit, but he also wanted to use the country's limited energy resources wisely. However, he did not want the beauty of the country and the eye health of his people to deteriorate. The sky, the stars and the moon look very beautiful in the evening and protect the eye health of the people in his country. He tried but couldn't find a way to do it. He asked his vizier to find a way to organize a contest. The winner of the contest will be the person who finds the best way to use electricity resources economically, designs the best lighting, doesn't spoil the beauty of the country and protects people's eyes. The winner also had to explain how to use the lights. The king said the winner of the competition would be his vizier. Asli and Ege, two young inventors, started planning how to win the contest.

What are the questions Aslı and Ege need to find the answers to? Write them down below.

1.question:

2. question:

3. question:

4. question:

Sample

The school where this study was carried out was selected by using the convenient sampling method, and in this respect, a public primary school located in the Yozgat province of Türkiye was preferred. Two classes with similar class sizes and similar gender distribution at the fourth-grade level in this school in the 2023-2024 academic year were chosen by using the simple random sampling method while forming both groups. Data regarding the students in groups are displayed in Table 1.

Table 1
Information About the Students in the Sample Group

Group	Grade Level	Gender		Total
		Girls	Boys	
Experimental Group	Fourth Grade	13	11	24
Control Group	Fourth Grade	12	10	22

As presented in Table 1, the experimental group is comprised of 24 students (13 Girls, 11 Boys) while the control group involves 22 students (12 Girls, 10 Boys). Even though the number of students in both groups is different, the gender distribution of the groups is similar. Moreover, placing the classes in two groups in the same school stemmed from the fact that the students could be ensured to live in similar environments and show similar socio-economic and cultural characteristics. Necessary permissions were obtained from the school where the study would be conducted, using ethics committee permission. The researcher interviewed the teacher of the class in which the study would be conducted and the students, and as a result of this interview, the teacher and students took part in the study voluntarily. Lastly, throughout the practice, all students in both groups participated in all the activities and showed no attendance problems throughout the process.

The Process and Practice

To achieve the aims of the study, four different scenarios regarding the target concepts were developed. In order to save time, these scenarios began to be practiced in the experimental group during the week following

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the development of each scenario. The model for the practice of scenario-based learning developed by Cerrah-Ozsevgec and Kocadag (2013) was utilized to practice the scenarios in the experimental group. In this model, the scenarios prepared are read by the students, and problems are created by the students depending on the scenarios read. These problems are tried to be solved by the students. If there are different or contradictory ideas regarding the solution of the problems, peer persuasion is performed. Finally, the process is evaluated together with the students. In Turkey, science lessons are included in the curriculum at the 4th-grade level of primary school for three hours a week. During the first lesson, the scenarios were read first silently and individually by the students and then read aloud by a selected student. Based on the scenario read, the students were asked to create a research problem. Similar problems were combined by discussing the problems created by the students. Students decided on the problem they wanted to solve and presented different solution methods to solve the problem. Discussions were held about solution methods, and any opposing ideas were tried to be resolved through peer persuasion. Students researched the solution they determined and presented their research results to the class with the method they chose. Following the presentations, the entire process was discussed and evaluated in the classroom. In the control group, the same topics and concepts were taught by using the activities in the textbook and smart board activities. Activities in EBA (Education Information Network), which is frequently used by classroom teachers in Turkey, were utilized in smart board activities. Data collection tools were initially performed with both groups as a pre-test, and then scenario-based learning activities were practiced in the experimental group, as mentioned above. Before the application, the teachers were provided with theoretical information by the researcher about scenario-based learning and the practice processes of the developed scenarios. Besides, the teachers working in the experimental and control groups had a master's degree and were willing to practice. After a 10-week application, three hours a week, the process was finalized by applying the data collection tools as a post-test in both groups.

Data Collection Tools

The data to achieve the aims of the current study were collected through the Science Scientific Creativity Questionnaire and the Science Reflective Thinking Scale developed by Guler (2024a).

Science Scientific Creativity Questionnaire

This questionnaire, developed by Guler (2024a), is designed specifically for the field of science for the fourth-grade level and measures all dimensions of the scientific creativity model suggested by Hu and Adey (2002) (i.e. science knowledge, science problem, science phenomena, technical product, flexibility, fluency, originality, thinking and imagination). The tasks regarding the validity and reliability of the questionnaire were carried out by Guler (2024a), and the content validity of the questionnaire, which consists of seven items, was calculated to be 100%. The Cronbach Alpha value of the questionnaire in question was calculated to be .901 (Guler, 2024a), which suggests that it has a high level of reliability since it is between .80 and 1.00 (Büyüköztürk, 2008). The questionnaire was preferred because it was specific to the field of science at the fourth grade level, and its validity and reliability studies had been performed. The scoring procedure suggested by Guler (2024a) was utilized so as to score the survey. The inter-rater reliability was observed to be 88% in the scoring performed by the three experts mentioned before.

Science Reflective Thinking Scale

This 5-point Likert scale, developed by Guler (2024a), includes the sub-dimensions of understanding, reflection, and critical reflection specific to the field of science at the fourth-grade level. The tasks regarding the scale's validity and reliability were executed by Guler (2024a), and the total variance explained by the scale's three-dimensional structure was determined to be 66.59%. The Cronbach Alpha coefficient of the entire scale was realized to be .95, and the Cronbach Alpha coefficients of the sub-dimensions (understanding, reflection, critical reflection) were .88, .93, and .89, respectively (Guler, 2024a). The fact that these values are higher than .80 for the sub-dimensions and the entire scale suggests that it is highly reliable (Büyüköztürk, 2008). Furthermore, the item-total correlation of all items in the scale is observed to be above .30, which shows that the discrimination of the items is high (Büyüköztürk, 2008).

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Data Analysis

For comparing both groups (i.e. the experimental and control group), the current study benefited from an independent samples t-test with the SPSS 21.0 Package program (see Table 2 and Table 5) as the data obtained from the Science Scientific Creativity Questionnaire and the Science Reflective Thinking Scale did not show a significant difference in the scores obtained by the groups from the pre-test. The dependent sample t-test was utilized in order to make comparison between the groups, and the analysis results are presented in tables.

When a significant difference was realized between the pre- and post-test scores while comparing the groups within themselves and with each other, the effect size (Hedge's g) was calculated. In cases where the sample size is less than 50, Hedge's g value makes a more sensitive measurement than Cohen's d (Thalheimer & Cook, 2002). The obtained Hedges' g values were interpreted by the following criteria: $g < 0.14$ "Negligible", $0.15 < g < 0.39$ "Low effect", $0.40 < g < 0.74$ "Medium effect", $0.75 < g < 1.09$ "Large effect", $1.10 < g < 1.44$ "Very large effect" and $g \geq 1.45$ "Excellent large effect" (Guler et al., 2022).

Research Results

Science Scientific Creativity

The pre-test scores of both groups were subject to an independent samples t-test analysis for the total score and all sub-dimensions (i.e. fluency, flexibility, originality) of scientific creativity skills (see Table 2).

Table 2
Scientific Creativity in Science Pre-Test Results

Sub-dimension	Group	*N*	*M*	*SD*	*SEM*	*F*	*t*	*df*	*p*	M_2-M_1	*SE*difference
Fluency	E	24	3.95	2.37	.48	0.090	0.739	44	.462	0.503	.681
	C	22	3.45	2,24	.47						
Flexibility	E	24	1.33	1.27	.26	0.801	0.665	44	.508	0.242	.364
	C	22	1.09	1.19	.25						
Originality	E	24	0.83	0.96	.20	0.233	0.601	44	.546	0.151	.252
	C	22	0.68	0.71	.15						
Total Score	E	24	6.13	4.06	.83	0.560	0.790	44	.434	0.897	1.143
	C	22	5.23	3.66	.77						

E= Experimental Group, C= Control Group, M= Mean, SD= Std. Deviation, SEM= Std. Error Mean, SEdifference= Std. Error Difference

As Table 2 reveals, there is no statistically significant difference between the pre-test scores of both groups in terms of all sub-dimensions of scientific creativity and total scores. As no significant difference was observed between the pre-tests, the pre- and post-test difference scores of both groups were exposed to an independent samples t-test (see Table 3).

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Table 3
Science Scientific Creativity Survey Difference Score Independent Samples T-Test Results

Sub-dimension	Group	*N*	*M*	*SD*	*SEM*	*F*	*t*	*df*	*p*	M_2-M_1	*SE*difference	Hedges' *g*
Fluency	E	24	2.83	1.46	.298	8.74	7.78	44	.005	2.651	.340	2.304
	C	22	0.18	0.66	.141							
Flexibility	E	24	2.50	0.93	.190	1.80	8.90	41	p < .001	2.136	.240	2.239
	C	22	0.36	0.65	.140							
Originality	E	24	2.54	1.25	.255	4.61	6.69	40	p < .001	2.132	.318	1.985
	C	22	0.40	0.85	.182							
Total Score	E	24	7.91	2.71	.554	10.81	11.09	31	p < .001	6.962	.627	3.283
	C	22	0.95	1.17	.250							

E= Experimental Group, C= Control Group, M= Mean, SD= Std. Deviation, SEM= Std. Error Mean, SEdifference= Std. Error Difference

As shown in Table 3, there is a significant difference in favor of the experimental group in the sub-dimensions of fluency, flexibility, originality, and total scores of scientific creativity. Additionally, the effect sizes (Hedges' g) of the differences between the pre- and post-test scores of the scientific creativity skill, including fluency, flexibility, originality, and total scores of both groups, were calculated to be 2.304, 2.239, 1.985, and 3.283, respectively. Thus, the differentiation observed for the experimental group in all sub-dimensions can be claimed to have a perfect large effect value (Hedges' g > 1.45).

Dependent samples t-test was performed to observe the differences in the pre- and post-test scores belonging to the experimental group and the control group (see Table 4).

Table 4
Pre-test and post-test results of the experimental group and control group with which the Science Scientific Creativity Questionnaire was applied.

Sub-dimension	Group	*N*	*M*	*SD*	*SEM*	*t*	*df*	*p*	M_2-M_1	Hedges' *g*
Fluency	E	24	2.83	1.464	.298	9.47	23	p < .001	2.833	1.911
	C	22	0.18	0.664	.141	1.28	21	.213	0.181	-
Flexibility	E	24	2.50	0.932	.190	13.13	23	p < .001	2.500	2.648
	C	22	0.36	0.657	.140	2.59	21	.017	0.363	0.546
Originality	E	24	2.54	1.250	.255	9.95	23	p < .001	2.541	2.007
	C	22	0.40	0.854	.182	2.24	21	.036	0.409	0.474
Total Score	E	24	7.91	2.717	.554	14.27	23	p < .001	7.916	2.877
	C	22	.954	1.174	.250	3.81	21	.001	.954	0.804

E= Experimental Group, C= Control Group, M= Mean, SD= Std. Deviation, SEM= Std. Error Mean

As Table 4 indicates, a significant difference was observed between the fluency, flexibility, originality, and total pre- and post-test scores belonging to the experimental group. The effect sizes of sub-dimensions of fluency, flexibility, originality and total scores belonging to the experimental group were determined to be 3.73, 5.17, 3.92, and 5.62, respectively, and these values fall within the perfectly large effect range (Hedges' g >1.45). No significant difference was observed in the sub-dimension of fluency between the pre- and post-test scores of the control group. However, a statistically significant difference was found in the flexibility, originality, and total pre- and post-test scores of the control group. For the control group, the effect sizes in sub-dimensions of flexibility and originality

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were 1.06 and .91, respectively. Both sub-dimensions fall within the large effect range (0.75 < Hedges' g < 1.09). The effect size of the total score is 1.56, which falls within the perfectly large effect range (Hedges' g > 1.45).

Reflective Thinking

The pre-test scores of both groups were subject to an independent samples t-test in terms of the total score and all sub-dimensions (i.e. understanding, reflection, critical reflection) of reflective thinking skills (see Table 5).

Table 5
Pre-test Results of Reflective Thinking Scale in Science

Sub-dimension	Group	*N*	*M*	*SD*	*SEM*	*F*	*t*	*df*	*p*	M_2-M_1	*SE*difference
Understanding	E	24	13.54	5.17	1.05	0.576	0.375	43	7.08	0.541	1.443
	C	22	13	4.55	.714						
Reflection	E	24	12.33	5.03	1.027	0.251	0.400	43	.690	0.560	1.402
	C	22	11.77	4.41	.941						
Critical Reflection	E	24	11.16	3.50	.713	0.083	0.492	43	.623	0.484	.985
	C	22	10.68	3.16	.672						
Total Score	E	24	37.04	12.83	2.620	0.835	0.447	44	.655	1.587	3.551
	C	22	35.45	11.07	2.361						

E= Experimental Group, C= Control Group, M= Mean, SD= Std. Deviation, SEM= Std. Error Mean, SEdifference= Std. Error Difference

As shown in Table 5, the pre-test scores of the two groups do not show a statistically significant variation across all sub-dimensions of reflective thinking and the total scores. Given that the pre-test scores did not differ significantly, an independent samples t-test was used to analyze the difference scores between the pre- and post-tests of the groups (see Table 6).

Table 6
Science Reflective Thinking Scale Difference Score Independent Samples T-Test Results

Sub-dimension	Group	*N*	*M*	*SD*	*SEM*	*F*	*t*	*df*	*p*	M_2-M_1	*SE*difference	Heges' *g*
Understanding	E	24	5.33	1.04	.214	0.673	13.40	44	p < .001	3.696	.275	4.17
	C	22	1.63	0.78	.168							
Reflection	E	24	4.50	2.02	.412	0.484	3.28	44	.002	1.727	.526	0.97
	C	22	2.77	1.47	.315							
Critical Reflection	E	24	3.16	1.78	.364	0.033	0.209	43	0.837	0.121	.580	
	C	22	3.04	2.14	.458							
Total Score	E	24	13	2.82	.577	0.367	6.174	41	p < .001	5.545	.898	1.82
	C	22	7.45	3.26	.695							

E= Experimental Group, C= Control Group, M= Mean, SD= Std. Deviation, SEM= Std. Error Mean, SEdifference= Std. Error Difference

As shown in Table 6, there exists a significant difference in the comprehension, reflection sub-dimensions, and total scores of reflective thinking for the benefit of the experimental group. However, any significant difference was not observed between the groups in the critical reflection sub-dimension (p > 0.05). Moreover, the effect

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sizes (Hedges' g) with regard to the differences observed between the pre- and post-test scores that belong to the sub-dimension of the scientific creativity skill comprehension, reflection, and total scores of both groups were calculated to be 4.17, .97, 1.82, respectively. In this regard, the difference in the comprehension sub-dimension and total scores of the reflective thinking of the experimental group in comparison to other group can be claimed to have an excellent large effect value (Hedges' g > 1.45), whereas the reflection sub-dimension has a low effect (Hedges' g > 1.10).

Dependent samples t-test was carried out in order to examine the differences in the pre- and post-test scores of the experimental group and control group (see Table 7).

Table 7

Pre- and Post-Test Results of the Experimental and Control Groups with which the Reflective Thinking Scale was Applied

Sub-dimension	Group	*N*	*M*	*SD*	*SEM*	*t*	*df*	*p*	M_2-M_1	Hedges' *g*
Understanding	E	24	5.33	1.04	0.214	24.89	23	P< 0.05	5.33	5.590
	C	22	1.63	0.78	0.168	9.72	21	P< 0.05	1.63	2.068
Reflection	E	24	4.50	2.02	0.412	10.90	23	P< 0.05	4.50	2.199
	C	22	2.77	1.47	0.315	8.80	21	P< 0.05	2.77	1.864
Critical Reflection	E	24	3.16	1.78	0.364	8.68	23	P< 0.05	3.16	1.753
	C	22	3.04	2.14	0.458	6.64	21	P< 0.05	3.04	1.540
Total Score	E	24	13	2.82	0.577	22.51	23	P< 0.05	13	4.551
	C	22	7.45	3.26	0.695	10.71	21	P< 0.05	7.45	2.261

E= Experimental Group, C= Control Group, M= Mean, SD= Std. Deviation, SEM= Std. Error Mean

As presented in Table 7, a significant difference was realized between the sub-dimensions of comprehension, reflection, critical reflection, and total pre- and post-test scores of the experimental group. Additionally, a significant difference was found between the comprehension, reflection, critical reflection, and total pre- and post-test scores that belonged to the control group. The effect size values of all sub-dimensions and total scores which belonged to both groups were examined, and all of them were found to fall within the perfect large effect (Hedges'g > 1.45).

Discussion

A statistically significant difference was observed between the post-test scores of both groups, which seemed to the benefit of the experimental group with regard to fluency, flexibility, originality, and total score of scientific creativity, and this difference had an excellent large effect value. This difference between the experimental group and the control group is thought to result from the content of scenario-based learning activities. As many research problems are created from the scenarios by students, different suggestions for solutions are offered for those selected to be solved, which is thought to be related directly to the fluency and flexibility sub-dimensions of scientific creativity (Hu & Adey, 2002; Kaya, 2010). Furthermore, the fluency sub-dimension is intertwined with flexibility, which can be expressed as producing a large number of ideas about a topic or as generating a large number of ideas in different categories (Hu & Adey, 2002; Torrance, 1990). What is more, the discussion and peer persuasion in the scenario implementation stages may also have caused this difference in the fluency and flexibility sub-dimensions (Cremin et al., 2015; Hu & Adey, 2002; Powers, 2015). The difference in the originality sub-dimension is thought to stem from the fact that students propose solutions to the problems they pose, conduct research on these solutions they suggest, and present their results to their peers, since students were guided only by clues and were left as free as possible. The lack of restrictions on students is considered to cause this difference in originality scores (Hu & Adey, 2002). The post-test scores belonging to the experimental group showed statistically significant difference in comparison to the pre-test in terms of fluency, flexibility, originality, and total scores, and that differentiation had an excellent large effect value for all sub-dimensions. In the control group, a significant difference was realized in the post-test scores when they were compared to the pre-test scores in terms of flexibility, originality,

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and total score. This difference was found to be in the range of a large effect in the flexibility and originality sub-dimension and to have a perfectly large effect on the total score. This difference, which emerged in terms of all sub-dimensions of scientific creativity and the total score in the experimental group, is thought to result from the content of scenario-based activities, posing scenario-related problems, offering numerous solution suggestions, researching from sources chosen by the student, persuading his peers for his solution in case of disagreement, and discussions throughout the process. This is because the activities in which students can put forward many ideas are very limited in these textbooks. The difference in terms of flexibility, originality, and total score may stem from the smart board activities used because the activities in question often include activities that aim at the flexibility sub-dimension such as categorization and design activities (such as preparing a plate that complies with healthy eating rules with a large variety of food). The difference in the originality sub-dimension in both groups may also be related to the number of students in the groups, which stems from the fact that the originality score of the ideas increases as the number of individuals decreases (Hu & Adey, 2002).

The comprehension and reflection sub-dimensions and total scores of the reflective thinking skill differ statistically significantly favoring the experimental group, and this differentiation has a perfectly large effect on the comprehension sub-dimension and total scores and a low effect value on the critical reflection dimension. This finding is consistent with Gulmez-Gungormez et al. (2016)'s study. Hence, it is thought that this difference is likely to stem from the fact that the scenarios include daily life situations, students manage the research process through collaborative discussions, and experience processes such as peer persuasion (Rogers, 2002; Taggart & Wilson, 2005; Ünver, 2003). In addition, problem-posing tasks may have supported the comprehension and reflection sub-dimensions of reflective thinking (Haigh, 2000). It can be said that the reflective thinking skill, especially at the peer persuasion stage, is closely related to the reflection and critical reflection sub-dimensions as students try to change their peers' minds by using their prior knowledge and the data they obtained from the research. Because this situation includes the evaluation of the advantages and disadvantages of ideas, it may cause differences in the reflection and critical reflection dimensions of reflective thinking (Huges et al., 1997; Rogers, 2002). The post-test scores that belonged to the experimental group and the control group were realized to differ statistically significantly compared to the pre-test scores in terms of all sub-dimensions of reflective thinking (understanding, reflection, critical reflection) and the total score. It was observed that this differentiation had an excellent large effect value for both groups and all sub-dimensions, which may have resulted from activities such as posing problems, offering solution suggestions, conducting research, group discussions about solution suggestions and research, and peer persuasion in the scenarios for the experimental group (Errington, 2011; Huges et al., 1997). The difference in the control group, nevertheless, may stem from the activities in the textbooks and smart board activities, as the subject was covered with the activities in the textbook and reinforced in the classroom through smart board activities. The content of the activities in the textbook often includes discussion sections and areas in which students can write their ideas and opinions, which may have enabled students an opportunity to understand the subject in depth and develop reflective thinking with all its sub-dimensions (Rogers, 2002; Tao & Zhang, 2018).

Conclusions and Implications

In the current study, which examined the impacts of scenario-based science activities on the scientific creativity and reflective thinking skills of fourth-grade students studying in primary school, the science lesson was taught via ten weeks of scenario-based science activities in the experimental group, and by using the activities in the textbook and smart board activities in the control group. This situation constitutes the limitation of the current study.

The present study, which benefited from the science scientific creativity survey and the science reflective thinking scale as data collection tools, indicated a statistically significant difference between the scientific creativity pre- and post-test total scores belonging to the experimental group and their scores on all sub-dimensions (fluency, flexibility, originality). Furthermore, the experimental group displayed statistically significant differences from the control group across all sub-dimensions of scientific creativity. Additionally, the control group's post-test scores differed significantly from their pre-test scores in terms of flexibility, originality, and total score.

The reflective thinking skill was observed to differ statistically significantly favoring the experimental group with regard to understanding and reflection sub-dimensions and total scores. Furthermore, the experimental group demonstrated statistically significant differences between their post-test and pre-test scores across all sub-dimensions of reflective thinking, as well as the total score. Similarly, the control group's post-test scores differed statistically significantly from their pre-test scores in all sub-dimensions of reflective thinking and the overall score.

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These findings suggest that scenario-based science activities developed scientific creativity in all its sub-dimensions more than the method practiced in the control group. Furthermore, scenario-based learning activities were found to improve the reflective thinking skill in all its sub-dimensions (understanding, reflection, critical reflection), and the comprehension and reflection sub-dimensions of reflective thinking were realized to improve more in the experimental group in comparison to the method practiced in the control group.

The results suggest that students are provided more space in science lessons for problem posing, offering solution proposals, peer persuasion, and research activities, which are included in scenario-based learning activities because they develop reflective and creative thinking skills. At the primary school level, it is recommended to teach with scenario examples, especially those that consist of fictional characters but contain real-life situations. Moreover, more studies are recommended to be conducted on scenario-based science activities, and more examples should be created so that teachers can benefit from them in lessons and researchers can utilize them in their studies. In future studies, the relationship between the level of problem-posing and scientific creativity skills can be examined, as well.

References

Akar, H., & Yadigaroğlu, M. (2021). The effect of the science, technology, engineering, and mathematics (STEM) based activities on the 5th grade students' association of the concepts in the substance and change unit with daily life. Erzincan University Journal of Education Faculty, 23(1), 57–81. https://doi.org/10.17556/erziefd.656886

Altın, M., & Saracaloglu, A. S. (2018). Creative, critical, and reflective thinking: Similarities-differences. International Journal of Contemporary Educational Studies, 4(1), 1–9.

Atabas, U. (2020). The effect of STEM education on fourth grade students' scientific creativity, reflective thinking skills for problem solving and opinions on STEM education in the science course [Doctoral dissertation], Marmara University.

Avcı, D., & Bayrak, E. B. (2013). Investigating teacher candidates' opinions related to scenario-based learning: An action research. Elementary Education Online, 12(2), 528–549.

Bayrak, E. B. (2010). Investigation on the opinions of science teacher candidates related to scenario-based learning: An action research [Master's thesis], Mehmet Akif University.

Bhakti, Y. B., & Astuti, I. A. D. (2018). The influence process of science skill and motivation learning with creativity learn. Journal of Education and Learning, 12(1), 30–35. https://doi.org/10.11591/edulearn.v12i1.6912

Büyüköztürk, S. (2008). Sosyal bilimler için veri analizi kitabı [Data analysis book for social sciences]. Pegem A Press.

Bybee, R. (2015). Scientific literacy. In R. Gunstone (Ed.), Encyclopedia of science education (pp. 944–947). Springer.

Cakir, U., & Kılcan, B. (2022). The effects of scenario-based training on disaster-related information and attitude levels of secondary school students. International Journal of New Approaches in Social Studies, 6(2), 183–205. https://doi.org/10.38015/sbyy.1175589

Cavusoglu, S. (2022). Investigation of scientific creativity of primary school fourth grade students in terms of various variables: Giresun province example [Master's thesis], Ordu University.

Cerrah-Ozsevgec, L. C., & Kocadag, Y. (2013). The effects of scenario-based learning approach to overcome the students' misconceptions about inheritance. Hacettepe University Journal of Education, 28(3), 83–96.

Ciraj, A. M., Vinod, P., & Ramnarayan, K. (2010). Enhancing active learning in microbiology through case-based learning: Experiences from an Indian medical school. Indian Journal of Pathology and Microbiology, 53(4), 729–733. https://doi.org/10.4103/0377-4929.72058

Cremin, T., Glauert, E., Craft, A., Compton, A., & Stylianidou, F. (2015). Creative Little Scientists: Exploring pedagogical synergies between inquiry-based and creative approaches in early years science. Education 3-13, 43(4), 404–419. https://doi.org/10.1080/03004279.2015.1020655

Errington, E. (2011). As close as it gets: Developing professional identity through the potential of scenario-based learning. In N. Jackson (Ed.), Learning to be professional through higher education (pp. 1–15). Surrey Centre for Excellence in Professional Training and Education. (1st ed.). https://www.lifewideeducation.uk/uploads/1/3/5/4/13542890/c3._edward_errington.pdf

Flynn, A. E., & Klein, J. D. (2001). The influence of discussion groups in a case-based learning environment. Educational Technology, Research and Development, 49(3), 71–86.

Guler, M., Butuner, S. O., Danisman, S., & Gursoy, K. (2022). A meta-analysis of the impact of mobile learning on mathematics achievement. Education and Information Technologies, 27, 1725–1745. https://doi.org/10.1007/s10639-021-10640-x

Guler, T. (2024a). The effect of inquiry-based science activities on elementary school fourth grade students' scientific creativity and reflective thinking skills [Doctoral dissertation], Trabzon University.

Guler, T. (2024b). Scenario-based learning in science education. In M. Alanoglu (Ed.), Eğitim&Bilim 2024-1 (pp. 1–15). Efe Akademi Press.

Guler, T. (2024c). An examination of the 2024 primary school science curriculum in terms of its alignment with science literacy. 10th International Eagean Congresson Scial Science & Humaity. 5-7 October. Izmir, Türkiye.

Gulmez-Gungormez, H., Akgun, A., & Duruk, U. (2019). The development of reflective thinking skills in students as a key objective of scenario-based learning. The Journal of Academic Social Science Studies, 7(48), 459–475. https://doi.org/10.9761/JASSS3567

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Hafler, J. P. (1997). Case writing: Case writers' perspectives. In D. Boud & G. I. Feletti (Eds.), The challenge of problem-based learning (2nd ed., pp. 151–159). Kogan Page.
Haigh, N. (2000). Teaching teachers about reflection and ways of reflecting. Waikato Journal of Education, 6, 87–98. https://doi.org/10.15663/wje.v6i1.457
Hodson, G. (2011). Do ideologically intolerant people benefit from intergroup contact? Current Directions in Psychological Science, 20, 154–159. https://doi.org/10.1177/0963721411409025.
Hu, W., & Adey, P. (2002). A scientific creativity test for secondary school students. International Journal of Science Education, 24(4), 389–403. https://doi.org/10.1080/09500690110098912
Hughes, H. W., Kooy, M., & Kanevsky, L. (1997). Dialogic reflection and journaling. The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 70(4), 187–190.
Jongluecha, P., & Worapun, W. (2022). Developing grade 3 student science learning achievement and scientific creativity using the 6E model in STEAM education. Journal of Educational Issues, 8(2), 142–151. https://doi.org/10.5296/jei.v8i2.20049
Karaoglan, B. (2019). The effect of the scenario-based learning method on students' achievement in 3rd grade social studies course [Master's thesis], Ağrı İbrahim Çeçen University.
Karci, M. (2018). Examining the effect of using scenario-based teaching method based on STEM activities on students' achievement, career choice and their motivation [Master's thesis], Cukurova University.
Kaya, H. İ. (2010). Effects of the practices based on constructivist learning in teacher education on teacher candidates' tendencies of problem solving, critical thinking, and creative thinking [Master's thesis], Atatürk University.
Kemiksiz, C. (2016). Effects of using scenario-based learning method in 6th grade science classes on academic achievement, attitudes, and permanence [Master's thesis], Abant Izzet Baysal University.
Kozikoglu, İ., & Tunc, M. (2020). The relationship between secondary school students' reflective thinking tendencies towards problem solving and perceptions of problem-solving skills. İnönü University Journal of the Faculty of Education, 21(1), 87–101. https://doi.org/10.17679inuefd.433824
Mariappan, J., Angela, S., & Peter, G. S. (2004, June). Scenario-based learning approach in teaching statics. In Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition (pp. 1–7). California State Polytechnic University, Pomona.
McComark, A. J. (1971). Effects of selected teaching methods on creative thinking, self-evaluation, and achievement of students enrolled in an elementary science education method course. Science Education, 55(3), 301–307.
Next Generation Science Standards [NGSS]. (2013). Next generation science standards: For states, by states. The National Academies Press.
Organisation for Economic Co-operation and Development [OECD]. (2006). The future of education and 2030: A series of concept notes. http://www.oecd.org/education/2030project/teaching-andlearning/learning/learningcompass2030/OECD_Learning_Compass_2030_Concept_Note_Series.pdf
Ozkurt-Ozturk, B. (2019). The effect of scenario-based learning on the academic achievement, attitude, and retention of students in science education [Master's thesis], Nigde Omer Halis Demir University.
Ozturk, S., & Karakas, H. (2023). The effects of scenario-based instruction on scientific thinking habits, science lesson attitudes, and academic achievement of primary school students. Journal of Education for Life, 37(3), 764–779. https://doi.org/10.33308/26674874.2023373630
Powers, R. D. (2015). Student and teacher attitudes, experiences, and perceptions of integrated inquiry-powered design-based STEM units [Doctoral dissertation], University of Nebraska-Lincoln.
Razzouk, R. (2011). The effects of case studies on individual learning outcomes, attitudes toward instruction, and team shared mental models in a team-based learning environment in an undergraduate educational psychology course [Doctoral dissertation), Florida State University.
Roberts, D. A. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education (pp. 729–780). Lawrence Erlbaum Associates.
Rogers, R. R. (2002). Reflection in higher education: A concept analysis. Innovative Higher Education, 26(1), 37–57. https://doi.org/10.1023/A:1010986404527
Saglam, M., Turkmen, H., & Pekmez, E. (2016). Prospective science teachers' understanding of scientific literacy: A case study survey research. Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 10(2), 46–64.
Siddiqui, A., Khan, M., & Akhtar, S. (2008). Supply chain simulator: A scenario-based educational tool to enhance student learning. Computers and Education, 51(1), 252–261. https://doi.org/10.1016/j.compedu.2007.05.008.
Sjöström, J. (2015, June). Vision III of scientific literacy: Science education for sustainability. Abstract List of WEEC 2015. Paper presented at the World Environmental Education Congress (WEEC), Gothenburg, Sweden.
Smith, G. (1987). The use and effectiveness of the case study method in management education: A critical review. Management Education and Development, 18(1), 51–61. https://doi.org/10.1177/1350507687018001
Taggart, G. L., & Wilson, A. P. (2005). Promoting reflective thinking in teachers: 50 action strategies. Corwin Press.
Tao, D., & Zhang, J. (2018). Forming shared inquiry structures to support knowledge building in a grade 5 community. Instructional Science, 46(4), 563–592. https://doi.org/10.1007/s11251-018-9462-4
Thalheimer, W., & Cook, S. (2002). How to calculate effect sizes from published research: A simplified methodology. Work-Learning Research, 1(9), 1-9.
Torrance, E. P. (1990). Torrance test of creative thinking: Norms-technical manual. Scholastic Testing Service.
Ünver, G. (2003). Yansıtıcı düşünme [Reflective thinking]. Pegem Akademi.

Wendell, K. B., Wright, C. G., & Paugh, P. (2017). Reflective decision-making in elementary students' engineering design. Journal of Engineering Education, 106(3), 356–397. https://doi.org/10.1002/jee.20173
Yıldız, C. K. S. (2022). Effects of using scenario-based learning method in 6th grade science classes on academic achievement and permanence. Social Sciences Studies Journal, 5(46), 5372–5388.

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THE CONCEPT OF VIRUSES AMONG FIRST AND SECOND GRADE PRIMARY SCHOOL STUDENTS

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Abstract. *Everyone has been interacting with the outside world since birth, creating ideas about various objects or phenomena. The main aim of the research was to identify the concepts of primary school students about viruses. In addition to finding out the level of ideas, additional aims were to determine the effect of gender, the degree of education attended, the residence, the presence of a doctor in the family and the perceived vulnerability to disease (PVD). The research sample consisted of 173 first and second grade primary school students. The research tool consisted of three parts. The first part was sociodemographic variables, the next part was a questionnaire focusing on the perception of one's own health. In the last section of the research tool, a children's drawing was used to determine the level of respondents' ideas about viruses. The data were analyzed using descriptive, inferential and multidimensional statistics methods. In most cases, drawings of viruses were relatively accurate. The level of education attended and perceived infectiousness were shown to be significant factors influencing the level of students' ideas about viruses. Due to a non-representative sample, the study brings only preliminary results. The anthropomorphic elements were often present in students' drawings in the first grade, it would be appropriate to consider what visual material should be used in the teaching process.*

Keywords: *categorical system, children's drawing, conceptions of viruses, primary school students*

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Introduction

Viruses are currently a widely discussed topic, especially in connection with the recent coronavirus pandemic, which significantly impacted not only adults but also children. The lack of interaction with peers, school closures, fear of contagion, and concern for loved ones are just a few examples of how students' daily lives were affected. During the pandemic, the author encountered various pieces of information about viruses that were inconsistent with scientific reality. Given that children's perceptions differ greatly from those of adults, understanding their initial ideas about viruses is crucial. This knowledge could serve as a prerequisite for developing educational materials that address key problematic areas, potentially reducing misconceptions about viruses among students. The primary aim of this study is to assess the level of understanding primary school students have about viruses and to determine whether selected variables—such as gender, grade level, residence, presence of a doctor in the family, and perceived vulnerability to disease—play a role.

Misconceptions are defined as incorrect, erroneous, or incomplete understandings of concepts that diverge from scientific knowledge. These misconceptions exhibit several typical characteristics. First, they occur regardless of gender, age, social status, or cultural background. Second, individuals of different ages often use them to explain natural science phenomena. Third, misconceptions tend to resist conventional teaching methods. Fourth, they become integrated into students' cognitive structures alongside other information provided by teachers. Additionally, misconceptions are often simple explanations of reality—similar to the ideas proposed by ancient philosophers—which makes them easier for people to understand and believe. Lastly, misconceptions frequently arise from direct observation and media influence (Doulik et al., 2024; Jammeh et al., 2023; Leonard et al., 2014). The field of students' ideas about viruses, bacteria, or microorganisms in general was previously one of the few explored. Nevertheless, several authors have contributed valuable insights to this topic in the past, including Nagy (1953) and Kalish (1996). In recent years, however, the number of research papers examining these ideas has increased. Byrne et al. (2009) investigated the anthropomorphic and anthropocentric perceptions of children regarding microorganisms. The study

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involved a sample of over 400 primary school students. Data analysis revealed that students generally held negative attitudes toward microorganisms and largely ignored their positive roles. Anthropomorphic representations of microorganisms were especially prevalent among younger students. Prokop et al. (2016) examined whether a child's personal experience with illness influenced their perceptions of microorganisms. In this study, children were asked to draw what they imagined germs looked like. Results indicated that children who were sick more frequently depicted microorganisms as smaller and used darker colors in their drawings compared to those with less experience of illness. No significant effects of age or gender were observed. Approximately 50% of children drew microorganisms with circular shapes, often incorporating human features such as legs, hands, or mouths. Some drawings even portrayed microorganisms as human figures. Among the drawings, 50% included two hands, while 40% omitted hands entirely; a smaller proportion depicted four hands. Similarly, 49% of microorganisms were drawn with two legs, while 25% had no legs. Most children (71%) included only one microorganism in their drawings, while the remainder depicted two or more. The size of the drawn microorganisms ranged from 4 to 30 cm. Furthermore, 55% of participants used multiple colors in their illustrations, whereas 45% opted for single-color representations. Similar findings have been reported in other studies (e.g. Assante & Candel, 2020; Gregorio et al., 2019; Idoiaga et al., 2020; Karadon & Sahin, 2010; Milandri, 2004; Simon et al., 2017; Simonneaux, 2000; Tinuola, 2016). As mentioned earlier, studies focusing on children's understanding of viruses, bacteria, and microorganisms in general have been increasing. The heightened interest in students' conceptions of viruses in recent years is primarily attributed to the pandemic caused by SARS-CoV-2, which affected the entire world. Bray et al. (2021) conducted research examining children's representations of the coronavirus. This study involved 128 children aged 7 to 12 years from six countries: the United Kingdom, Australia, Sweden, Brazil, Spain, and Canada. According to the authors, nearly half of the drawings closely resembled the actual image of SARS-CoV-2. The virus was most frequently depicted as green, circular in shape, and adorned with spikes. The words chosen by children to describe the virus were typically menacing, diabolical, and evil. The illustrations also included details about transmission methods (e.g., sneezing, coughing, handling contaminated objects) and preventive measures (e.g., regular handwashing, disinfection, wearing masks, maintaining social distance). Martinerie et al. (2021) found that a red or green circle with a crown composed of spongy surface protrusions represented the most common cartoon depiction of the coronavirus among children. Additionally, 37% of the drawings included anthropomorphic features such as eyes, sad or smiling mouths, or sharp teeth; 24% were drawn in three dimensions. Bonotti et al. (2022) investigated children's perceptions of the coronavirus through drawings and verbal descriptions. Their findings revealed that children demonstrated a remarkable understanding of the coronavirus and its medical, social, and psychological impacts on people's lives from an early age. A significant proportion of children incorporated anthropomorphic elements into their drawings. Furthermore, no substantial differences in children's perceptions of the virus were observed across different age groups. Similar patterns in virus illustrations during the pandemic were reported in other studies. (Carlsson et al., 2023; Christidou et al., 2022; Duran, 2021; Pocsova et al., 2021; Qekaj-Thaqi & Thaqi, 2021; Walters et al., 2022).

Research Problem

The literature review indicates that studies utilizing drawings to assess participants' understanding of various biological phenomena encompass a wide range of age groups, from primary school students (e.g., Edelsztein, 2024) to adults (e.g., Waters et al., 2023). However, primary school students are underrepresented in the research samples, as greater attention is typically given to older students in elementary or high schools. This focus aligns with the developmental stage at which students form their final concepts about different phenomena, not limited to biology (Hadenfeldt et al., 2016). Identifying topics that pose challenges for these students and addressing any misconceptions they may hold is therefore crucial. Another significant issue is the limited coverage of viruses in the biology curriculum at Czech primary schools. The curriculum provides only fragmented information about viruses and their morphology, potentially leading to distorted perceptions among students regarding the appearance of viruses. Furthermore, there is a notable lack of research on this topic; existing studies have not sufficiently explained the phenomenon.

Research Focus

Research was focused on finding out the factors which can influence concepts about viruses. The main aim of the research was to identify the concepts of primary school students about viruses. The additional aims were to find out the influence of selected factors (gender, grade level, residence, presence of doctor and perceived vulner-

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ability to disease) on concepts about viruses among primary school students. In line with the aims, the focus of this research was to answer the following questions:

1. What are the primary school students' conceptions about viruses?
2. What is the influence of selected variables (gender, grade level, residence, presence of doctor and perceived vulnerability to disease) on primary school students' virus conception?

Research Methodology

General Background

The study employs a quantitative approach to collecting and analyzing data. To answer the research question, a research tool was administered to a sample of Czech primary school students. The tools were distributed in paper-and-pen form during the second term of the 2022/2023 academic year, and data collection lasted four months. Participation in completing the research tool was voluntary, and respondents' anonymity was guaranteed. No incentives were offered to those who provided responses. The study presents preliminary results of the research due to a non-representative sample.

Sample

The research was conducted during the 2022/2023 academic year at four primary schools in the Czech Republic. A non-random sampling method was employed for participant selection. Participants were not intentionally chosen but were based on the willingness of teachers to participate in the research. The schools were accessible to the researchers, who had personal contacts with the school directors. The research sample consisted of 173 primary school students who voluntarily participated in the study. The total number of 325 students was addressed. However, 53% agreed and filled out the questionnaire. Students from all years of the first and second grades were included. The study adhered to ethical guidelines and was approved by the Ethics Committee of the Faculty of Education, Jan Evangelista Purkyne University, under reference number 3/2022/02. The committee confirmed that the study complied with valid principles, regulations, and international guidelines for research involving human participants. A total of 96 students from the first level participated in the survey: 11 students from the first year, 21 from the second year, 17 from the third year, 27 from the fourth year, and 20 from the fifth year. At the second level, 77 students completed the questionnaire: 20 students from the sixth grade, 13 from the seventh grade, 20 from the eighth grade, and 24 from the ninth grade. Gender representation among respondents was relatively balanced, with 92 girls and 81 boys. The majority of participants (n = 131) came from rural backgrounds, while a smaller proportion (n = 42) were from urban areas. Additionally, 29 students reported having a doctor in their family. The age range of participants spanned from 7 to 16 years.

Tool

The research tool consisted of several parts. The introductory section included a description of the research aims, followed by information on its implementation and demographic variables. Demographic data collected included the respondent's gender, age, grade level, place of residence (village or city), and whether there was a doctor in the family. The second section of the research tool featured a questionnaire titled Perceived Vulnerability to Disease (PVD), comprising 21 Likert-type items measured on a 5-point scale (1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree). The first 14 items focused on perceived vulnerability. This questionnaire was originally developed and validated by Duncan et al. (2009). Among these 14 items, eight conveyed positive meanings, while six conveyed negative meanings. A higher score indicated greater perceived vulnerability. The questionnaire was divided into two sub-dimensions: perceived infectivity (items 1, 6, 8, 10, 12, and 14) and germ aversion (items 2, 3, 4, 5, 7, 9, 11, and 13).

The remaining seven items in the second section targeted perceived disgust. This questionnaire was initially used in a study by Fancovicova et al. (2013). Since it was originally written in Slovak, translating it into Czech posed minimal challenges. All items had positive connotations; higher scores reflected greater resistance levels. Items with negative meanings were reverse-coded. The final section of the research tool utilized numerical symbols within a categorical system for evaluation. To ensure methodological rigor, reliability testing was conducted for the sections incorporating Likert-type items – specifically, the perceived vulnerability questionnaire and its components.

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Cronbach's alpha (α) was calculated to assess reliability for both the entire questionnaire and its subcategories. The overall questionnaire achieved an α value of .74, indicating high reliability (Nunnally, 1978). Subcategories exhibited α values ranging from .64 to .72, demonstrating adequate reliability. Additionally, normality tests were performed using the Kolmogorov-Smirnov test (*d*) to determine whether parametric statistical methods could be applied to interval-level data. The test yielded a d value of .06 ($p > .20$), confirming normal data distribution. Normality tests for each questionnaire component also supported this finding; detailed results are presented in Table 1.

Table 1
Normality Values for Each Component of the Self-health Perception Questionnaire

Components of questionnaire	*d*	*p*
Perceived vulnerability	.05	> .20
Perceived resistance	.09	> .05
Perceived infectivity	.07	> .20
Germ aversion	.06	> .20

d – value of normality, *p* – level of significance

The final part of the research tool focused on respondents' ideas about viruses in general. To identify these ideas, the research method employed was children's drawings. Students were given blank A4-sized paper and asked to draw what they thought a virus looked like. This process is possible to find in some other studies, where some aspects of science (biological) education were examined (Chang, 2012; Howlett & Turner, 2023; Prokop & Fancovicova, 2006). Since no suitable categorical system for the purposes of the research could be found in specialist literature, a custom system was developed.

Categorical system for evaluating the level of respondents' ideas about viruses:

- Category 1 - Presence of coronavirus (subcategory: yes; no)
- Category 2 - Color of virus (subcategory: light; dark; colorless)
- Category 3 - Presence of an anthropomorphic element (subcategory: yes; no)
- Category 4 - Depiction of prevention strategy (subcategory: yes; no)
- Category 5 - Showing how the virus is transmitted (subcategory: yes; no)
- Category 6 - Number of viruses displayed (subcategory: one; two; three, or more)
- Category 7 - Number of virus shapes displayed (subcategory: one shape; multiple shapes).

Data Analysis

After completing the data collection, the data were first recoded into numerical form for statistical processing. The items from the second part of the research tool were recoded according to the points. In analyzing the data, two statistical approaches were employed to meet the research aims. The first approach involved considering the frequency of representation of each virus drawing category as the dependent variable and the average score of perceived vulnerability to disease and its individual components as the independent variable. In this case, analysis of variance (ANOVA) was used. Since some variables (drawing categories) contained more than two groups, Tukey's post-hoc test was applied to determine intra-group differences. This method is commonly used in socio-scientific research investigations (Maxwell, 1980; Sun, 2019).

The second statistical method was the chi-square independence test (χ^2), where independent variables had the character of nominal variables. The findings, through statistical analyses, are presented in verbal, tabular or graphical form. The statistical test results are reported at three levels of significance ($p < .05$; $p < .01$; $p < .001$). Microsoft Excel spreadsheet and statistical software STATISTICA 10.0 were used for data processing.

Research Results

In Figure 1, the distribution of scores across each category of a categorical system designed to evaluate respondents' perceptions of viruses is presented. Over 80% of respondents illustrated a virus resembling the coronavirus in shape. Less than 50% of the drawings employed dark colors, followed by those using light colors. The least frequent were "colorless" drawings, where students depicted the virus only in outline using a pencil or

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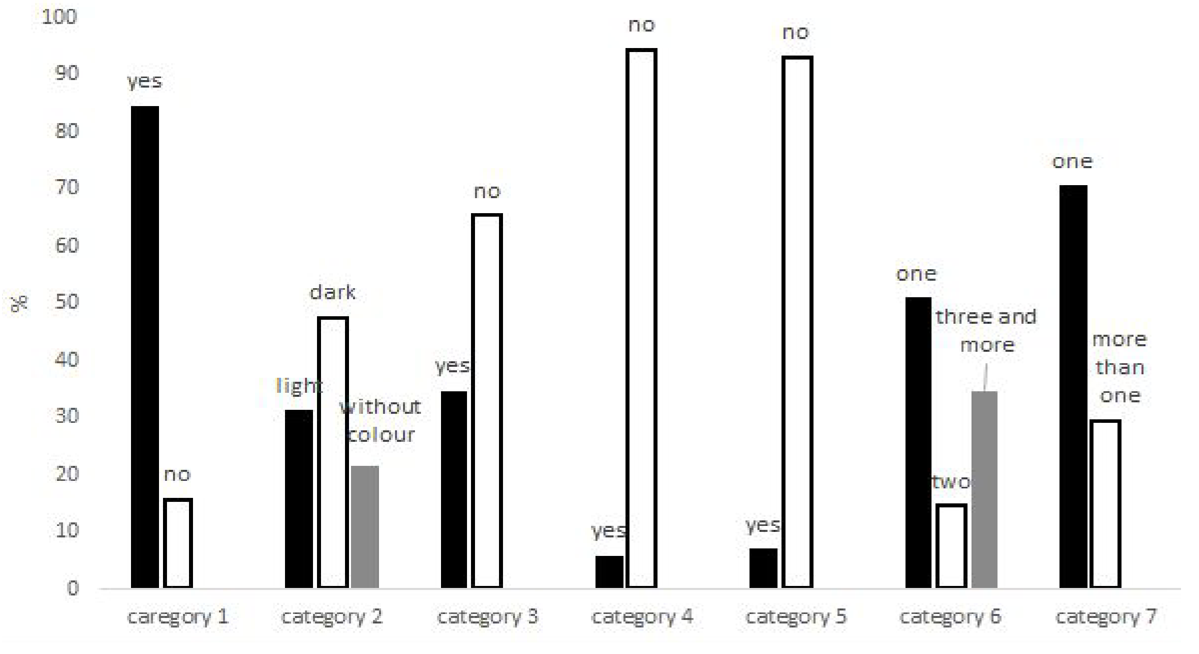
pen without adding color. Approximately one-third of the students incorporated anthropomorphic elements into their virus illustrations. A small proportion of drawings (just over 5%) included representations of preventive strategies or methods of virus transmission. Another category analyzed was the number of viruses depicted in the drawings. Half of the students illustrated a single virus, less than 35% included three or more viruses, and 15% depicted two viruses. Regarding the number of virus shapes displayed, 70% of the drawings featured one shape, while 30% included multiple shapes.

Figure 1
Score Distribution with Respect to Categories



The perceived vulnerability to disease and its individual components did not influence the perception of the virus or individual categories, except for perceived infectivity. Lower scores in perceived infectivity were observed among students whose drawings lacked representations of the mode of transmission. Table 2 presents an analysis of variance values, confirming the insignificance of these variables.

Table 2
Analysis of Variance Within Each Virus Perception Category with Respect to Health Perception

Variables	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6	Category 7
Perceived vulnerability to disease	.17	1.99	.21	.45	.55	.40	.18
Perceived vulnerability	.17	1.97	.001	.29	2.06	1.18	1.35
Perceived disgust	.06	1.38	.86	.32	.25	.09	.58
Perceived infectivity	.46	.03	.20	.14	7.30**	1.20	.75
Germ aversion	1.13	2.82	.10	.17	.05	.32	.68

** $p < .01$

Among the other variables, the gender of the respondents did not manifest significantly in any of the categories studied, similarly, the residence or presence of a doctor did not affect them. Only the grade attended proved to be a significant factor. A significant difference was determined in the category "color of the virus" ($\chi^2 = 35.70$; $p < .001$; $df = 2$). Since the above variable had more than two groups, z-score was used, and it was identified that

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first graders drew viruses with dark color to a significant extent ($p < .05$) and second graders drew more pictures without using color ($p < .001$).

A statistically significant difference ($\chi^2 = 7.83$; $p < .01$; $df = 1$) was also demonstrated for another observed category, the presence of an anthropomorphic element, depending on the grade level. Students attending first grade incorporated anthropomorphic elements into their drawings to a greater extent than students from second grade. For the category 'number of viruses displayed with respect to degree of education', a statistically significant difference in results was identified ($\chi^2 = 9.40$; $p < .01$; $df = 2$). Due to the fact that the above variable had more than two groups, the z-score was used, and it was found that the respondents attending the second grade showed more than one virus in their drawings compared to the first-grade students. A statistically significant difference was detected for the last category, called "number of displayed virus shapes," with respect to respondents' degree of education. Although both groups displayed only one shape of the virus more often in their drawings, the second-grade students drew them to a greater extent than the first-grade students ($\chi^2 = 5.05$; $p < .05$; $df = 1$). The individual values of the chi-square test are shown in Table 3.

Table 3

Chi-square Test Value (χ^2) Within Each Virus Perception Category with Respect to Demographic Variables

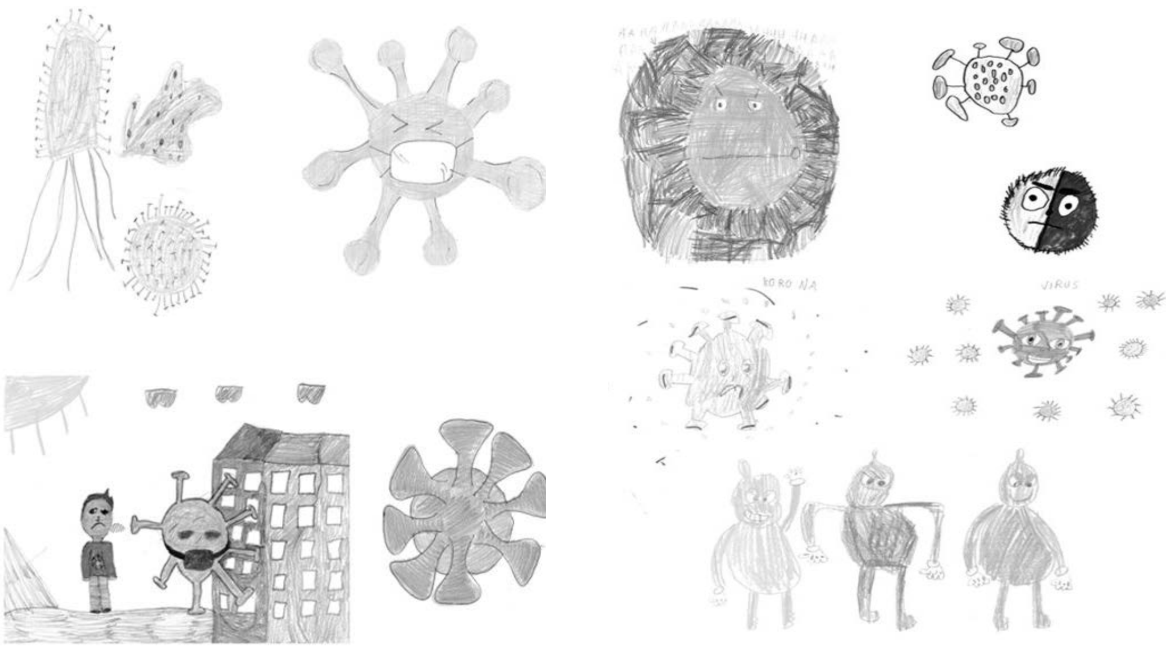
Variables	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6	Category 7
Gender	.98	1.87	.12	.20	.05	4.34	.39
Grade level	2.82	35.70***	7.83**	.90	.90	9.40**	5.05*
Residence	.50	1.90	.04	.19	0.04	2.50	3.23
Presence of a doctor	.73	5.49	2.84	.08	.07	.82	.04

* $p < .05$; ** $p < .01$; *** $p < .001$

Regarding the drawings themselves, first-grade students frequently depicted the coronavirus alongside other elements, such as shapes resembling amoebas, blood platelets, or centipedes. The viruses were often portrayed in green. Additionally, there were drawings illustrating preventive strategies or ways the virus could be transmitted (Figure 2).

Figure 2

Examples of Viruses Drawings by First Grade Students



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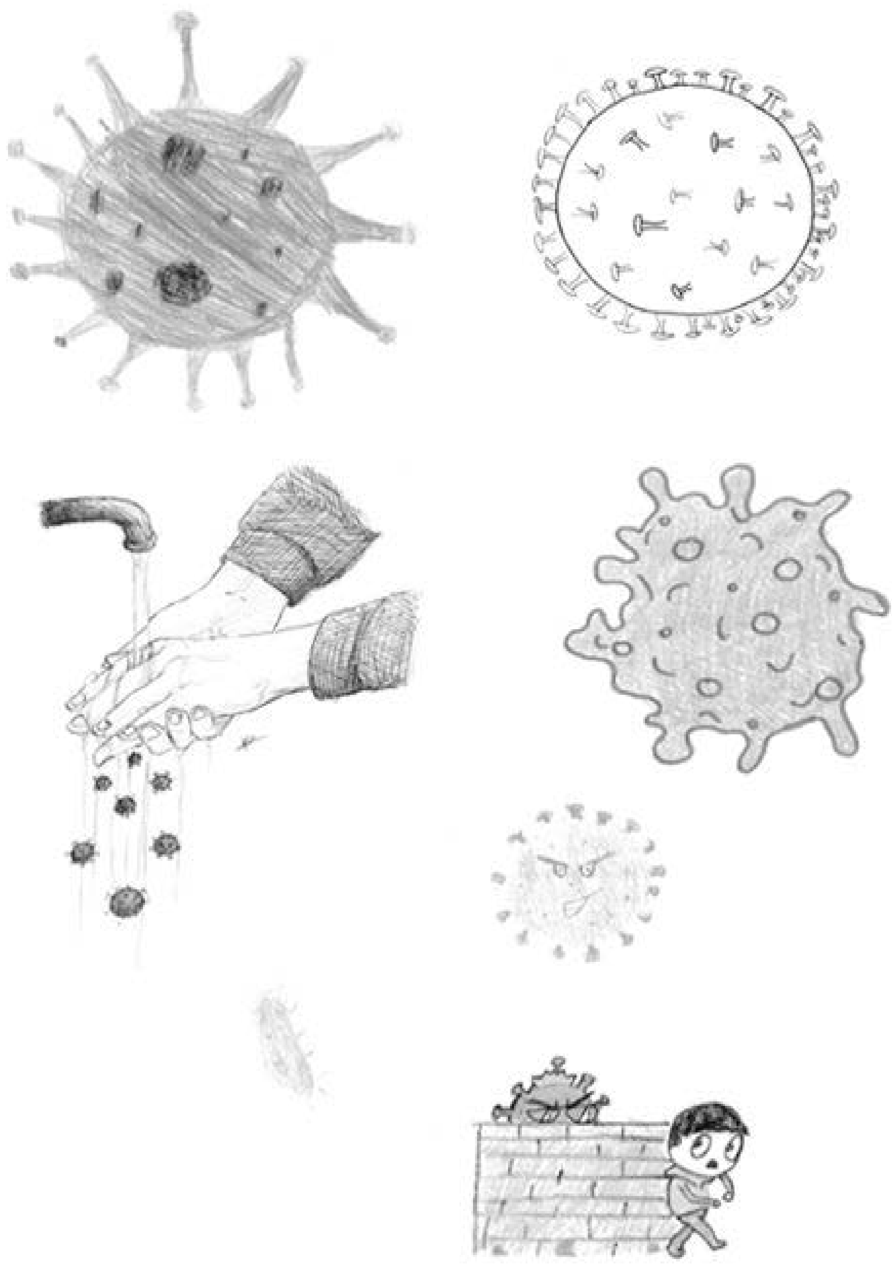
Examples of drawings by second-grade elementary school students are shown in Figure 3. The shapes attributed to viruses by second-grade students did not differ significantly from those drawn by first-grade students. The most common representation was the coronavirus shape, followed by centipede-like, oval, or iridescent shapes. One drawing included an attempt to depict a bacteriophage. While green remained the most used color, most second-grade drawings were created using a pencil or pen without coloring. Compared to first-grade drawings, fewer second-grade illustrations included anthropomorphic elements. Additionally, the names of certain viral diseases, such as Ebola and influenza, appeared in some drawings.

Figure 3
Examples of Virus Drawings by Second Grade Students



On the figures are represented only the typical drawings for the selected categories. The coronavirus was the most often represented type of virus among first and second grade students.

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Discussion

Through the children's drawings, it was identified that most students had relatively adequate ideas about viruses. Most commonly, respondents depicted a single virus with a circular shape and spikes. The most used color was dark green. A smaller portion of the drawings also contained anthropomorphic elements. The mode of transmission of the virus and the prevention strategies were rarely displayed.

Our findings were in concordance with other studies, for example, in a study by Bray et al. (2021), it was also found that drawings showed a considerable understanding of the form of viruses. Some of the drawings also contained anthropomorphic elements. A similar trend could be observed, for example, in studies by Martinerie et al. (2021) or Duran (2021). While respondents' overall depiction of viruses can be assessed as generally accurate, based on the results, it is possible to conclude that the child's image of the appearance of the virus is largely influenced by the media, in which visual images of the coronavirus, often also with anthropomorphic elements, were widely displayed during the pandemic (McGellin et al., 2021).

Although the main aim of this study was to find out students' concepts about viruses, it is evident that the pandemic crisis has significantly affected students in this area, as most of them recall the coronavirus as the virus. At the same time, studies suggest that even students perceived the medical, social and psychological effects of the coronavirus crisis not only on their lives, but also on the lives of their loved ones. "Another area of study was the gender difference in children's virus drawings. The results indicated that gender was not a significant factor. This finding agrees with the results of the authors Prokop et al. (2016), who devoted their work to, among other things, what ideas about microorganisms' children attending kindergartens have. The researchers cite authors such as Curtis et al. (2004), who argued that women should have different levels of understanding of microorganisms from men in evolutionary terms, due to the fact that women are more likely to care for children, and so their concern stemming from microorganisms and the child's subsequent illness is significantly higher.

Another factor influencing students' ideas about viruses was the degree of education attended, which was statistically significant in the results. In the presented study, a notable difference was observed in the categories of anthropomorphic elements, virus color, the number of viruses displayed, and the variety of virus shapes depicted. Data analysis revealed that first-grade students incorporated more anthropomorphic elements into their drawings compared to second-grade students.

These findings align with Byrne et al. (2009), who noted that anthropomorphic features decrease significantly with age in children's drawings. Anthropomorphism is a hallmark of preschool-aged children's artistic expression, making it understandable that older students displayed fewer anthropomorphic elements. Previous studies have demonstrated that students often use anthropomorphism to articulate ideas that are otherwise challenging to express due to limited scientific knowledge or technical terminology (Inagaki & Hatano, 1987). Furthermore, significant differences were identified in students' verbal descriptions; older students provided realistic and science-oriented explanations, while younger students employed anthropomorphic, mythic, or symbolic language.

In the virus color category, first-grade students were found to use dark colors to a significant degree, while second-grade students drew viruses without using color. These results can be explained in two ways. Firstly, younger students might prefer their drawings to be more colorful, while older students may be content with simpler drawings. Secondly, although less likely, older students might have already learned about viruses in class and therefore know that viruses themselves have no color, which is why they didn't attribute any to them. In the category of the number of viruses displayed, it was observed that statistically, respondents from the second stage (second grade) more frequently depicted a single virus compared to those from the first stage (first grade). This is linked to the previous significant results, where in the category of the number of displayed virus shapes, second-grade students were more likely to draw only one shape of a virus compared to first-grade students. This could be because older students are satisfied with simple, realistic drawings, while younger students want their drawings to be more detailed and sophisticated. It could also be based on the development of drawing skills, where younger school-age students are in a phase of visual realism. This period is characterized by students drawing everything they know about a given topic, resulting in drawings full of details. Around the beginning of second grade, the development of drawing comes to an end, and students enter a phase known as the crisis of visual expression. This phase is marked by increased self-criticism of their artistic expression, leading students to often resort to drawing mere diagrams or models. It is also worth mentioning the last two categories: the depiction of how the virus is transmitted and the depiction of preventive strategies. Although no significant differences were detected, younger students scored higher in both categories, meaning they more frequently included methods of virus transmission or preventive

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strategies in their drawings. This aligns with the findings of a study by Bonoti et al. (2022), where younger students also depicted virus transmission methods or pandemic restrictions to a greater extent.

The additional aim of the study was to determine whether the level of virus-related drawings varied based on the respondents' residence. The results revealed that residence did not statistically significantly influence the depiction of viruses in the drawings. However, slight differences were observed between urban and rural respondents. Urban students tended to include more preventive strategies and representations of virus transmission in their drawings. This may be attributed to their frequent exposure to viruses in public spaces such as transportation systems, shopping centers, and service facilities. For example, during the COVID-19 pandemic, preventive measures likely had a greater impact on urban residents than on those living in rural areas. Rural students were able to maintain physical distance more effectively, access nature freely, and avoid constant mask-wearing or frequent use of disinfectants. Conversely, rural students scored higher in categories such as the presence of coronavirus imagery, anthropomorphic elements, and depictions of a single virus shape. This could be due to their comparatively limited exposure to media, which serves as a primary source of information about viruses (e.g. Karadon & Sahin, 2010). No studies were identified during the research that specifically examined the correlation between respondents' residence (urban vs. rural) and their ability to depict viruses through drawings. Despite this gap in literature, similar studies conducted globally have yielded comparable results. Furthermore, the drawings included various slogans and characters associated with pandemic-related campaigns. For instance, some respondents from the United Kingdom incorporated the slogan "Catch it. Bin it. Kill it." from the British government's official hygiene promotion campaign during the COVID-19 pandemic.

Differences in students' understanding of viruses based on the presence of a doctor in their family were not identified. Respondents who reported having a doctor in the family more frequently included anthropomorphic elements in their drawings but depicted virus transmission methods less often. It was presumed that students with doctors in their families would be more informed about viruses or illnesses due to their communication with parents and exposure to discussions about viruses. These students were expected to demonstrate greater expertise compared to others. Contrary to this expectation, students with doctors in their families more frequently illustrated preventive strategies and the coronavirus in their drawings. This result may be attributed to the heightened vulnerability of healthcare professionals during the coronavirus pandemic, as they were in constant contact with infected individuals. Consequently, these professionals likely emphasized preventive measures and educated their children about them. The lack of statistically significant differences between categories suggests that all students were equally affected by the pandemic, regardless of their parents' occupations. The presence of a doctor in the family was not extensively examined as a demographic variable in prior research. Only one study by Martinerie et al. (2021) explored students' perceptions of the coronavirus, including whether their parents were healthcare professionals. This study found no significant association between parental occupation and students' perceptions of the coronavirus.

The final observed variable potentially influencing students' virus imagery levels was perceived vulnerability to disease. The questionnaire assessed respondents' self-perceived health through two subscales: perceived resistance and perceived vulnerability. While perceived resistance showed no significant association with any categories of interest, perceived vulnerability demonstrated a statistically significant effect. A marked difference emerged in depictions of viral transmission modes. Participants scoring higher in the perceived infectiousness subgroup more frequently depicted transmission mechanisms in their drawings. This aligns with the hypothesis that individuals who perceive themselves as more susceptible to infection may consciously recognize pathways through which pathogens could infect them. Notably, Stangier et al. (2022) have explored similar relationships between perceived vulnerability and health-related behavioral outcomes. No statistically significant differences were found in the depiction of preventive strategies; however, a marginally higher prevalence of such strategies appeared in drawings by students with elevated perceived vulnerability scores. A parallel trend occurred in the representation of coronavirus presence: respondents with higher perceived vulnerability scores more consistently included the virus in their illustrations. These findings echo work by Tare and Bendre (2022), who identified positive correlations between COVID-19 infection rates and both perceived infectiousness and germ aversion subscales. Comparable results have been documented in studies by Díaz et al. (2020) and González-Castro et al. (2021).

Limitations

The crucial limitations of the presented research are the sample size and the selection of respondents. The authors are aware that the sample size is not representative, on the basis of this fact, the study presents only pre-

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liminary results. The findings are interpreted with this limitation in mind, and a future study using a representative sample from more schools is recommended. Another limitation lies in the first-time use of the categorization system for virus drawings. Further research involving different age cohorts is needed to assess the usability of this system.

Conclusions and Implications

Anthropomorphic elements were frequently detected in first-grade students, suggesting the need to carefully select visual materials for teaching. The focus should be on addressing and eliminating this misconception. Regarding virus shapes, students predominantly depicted circular forms. To enhance understanding, it would be beneficial to present a more diverse portfolio of virus images showcasing various shapes. This study offers only a preliminary report on students' conceptualizations of viruses, highlighting opportunities for further research. Future investigations could incorporate conceptual maps to explore students' ideas about viruses more deeply. Analyzing the most commonly used words in these maps could provide additional insights. Complementary research methods, such as interviews with respondents, may also be valuable for gathering more detailed data.

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Declaration of Interest

The authors declare no competing interest.

References

Assante, G. M., & Candel, O. S. (2020). Students' views on the Covid-19 pandemic: Attitudes, representations, and coping mechanisms. *Postmodern Openings, 11*(4), 347–365. https://doi.org/10.18662/po/11.4/240

Bonoti, F., Christidou, V., & Papadopoulou, P. (2022). Children's conceptions of coronavirus. *Public Understanding of Science, 31*(1), 35–52. https://doi.org/10.1177/09636625211049643

Bray, L., Blake, L., Protheroe, J., Nafria, B., de Avila, M. A. G., Ångström-Brännström, C., Forsner, M., Campbell, S., Ford, K., Rullander, A.-C., Robichaud, F., Nolbris, M. J., Saron, H., Kirton, J. A., & Carter, B. (2021). Children's pictures of COVID-19 and measures to mitigate its spread: An international qualitative study. *Health Education Journal, 80*(7), 811–832. https://doi.org/10.1177/00178969211019459

Byrne, J., Grace, M., & Hanley, P. (2009). Children's anthropomorphic and anthropocentric ideas about micro-organisms: Educational research. *Journal of Biological Education, 44*(1), 37–43. https://doi.org/10.1080/00219266.2009.9656190

Carlsson, S., K Flensner, K., Svensson, L., & Willermark, S. (2023). Teaching vocational pupils in their pyjamas: A socio-material perspective on challenges in the age of Covid-19. *The International Journal of Information and Learning Technology, 40*(1), 84–97. https://doi.org/10.1108/IJILT-03-2022-0064

Chang, N. (2012). The role of drawing in young children's construction of science concepts. *Early Childhood Education Journal*, *40*, 187-193. https://doi.org/10.1007/s10643-012-0511-3

Christidou, V., Bonoti, F., Papadopoulou, P., Hatzinikita, V., & Doumpala, P. (2022). Children's views of SARS-CoV-2 and COVID-19 preventive practices: Comparing verbal and visual empirical evidence. *Frontiers in Education, 7*, Article 917442. https://doi.org/10. 3389/ feduc.2022.917442

Curtis, V., Aunger, R., & Rabie, T. (2004). Evidence that disgust evolved to protect from risk of disease. *Proceedings of the Royal Society of London. Series B: Biological Sciences, 271*(4), 131–133. https://doi.org/10.1098/rsbl.2003.0144

Díaz, A., Beleña, Á., & Zueco, J. (2020). The role of age and gender in perceived vulnerability to infectious diseases. *International Journal of Environmental Research and Public Health, 17*(2), Article 485. https://doi.org/10.3390/ijerph17020485

Doulik, P., Skoda, J., Bilek, M., & Prochazkova, Z. (2024). The changes of secondary school students' conceptions of science concepts. *Journal of Baltic Science Education*, *23*(6), 1164-1177. https://doi.org/10.33225/jbse/24.23.1164

Duncan, L. A., Schaller, M., & Park, J. H. (2009). Perceived vulnerability to disease: Development and validation of a 15-item self-report instrument. *Personality and Individual Differences, 47*(6), 541–546. https://doi.org/10.1016/j.paid.2009.05.001

Duran, M. (2021). Reflection of COVID-19 Pandemic on the drawings of pre-school children: A phenomenological study. *African Educational Research Journal, 9*(1), 86–99. https://doi.org/10.30918/AERJ.91.20.223

Edelsztein, V. (2024). Has the coronavirus pandemic changed students' conceptions of microorganisms? Evidence from elementary school. *International Journal of Science Education*, *46*(8), 733–749. https://doi.org/10.1080/09500693.2023.2256459

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Fancovicova, J., Prokop, P., & Leskova A. (2013). Perceived disgust and personal experiences are associated with acceptance of dissections in schools. *Eurasia Journal of Mathematics, Science and Technology Education, 9*(3), 311–318. https://doi.org/10.12973/eurasia.2013.938a

González-Castro, J. L., Ubillos-Landa, S., Puente-Martínez, A., & Gracia-Leiva, M. (2021). Perceived vulnerability and severity predict adherence to COVID-19 protection measures: the mediating role of instrumental coping. *Frontiers in Psychology, 12*, Article 674032. https://doi.org/10.3389/fpsyg.2021.674032

Gregorio Jr, E. R., Medina, J. R. C., Lomboy, M. F. T. C., Talaga, A. D. P., Hernandez, P. M. R., Kodama, M., & Kobayashi, J. (2019). Knowledge, attitudes, and practices of public secondary school teachers on Zika Virus Disease: A basis for the development of evidence-based Zika educational materials for schools in the Philippines. *PloS One, 14*(3), Article 0214515. https://doi.org/10.1371/journal.pone.0214515

Howlett, K., & Turner, E. C. (2023). What can drawings tell us about children's perceptions of nature?. *Plos One*, *18*(7), Article 0287370. https://doi.org/10.1371/journal.pone.0287370

Hadenfeldt, J. C., Neumann, K., Bernholt, S., Liu, X., & Parchmann, I. (2016). Students' progression in understanding the matter concept. *Journal of Research in Science Teaching, 53*(5), 683–708. https://doi.org/10.1002/tea.21312

Idoiaga, N., Berasategi, N., Eiguren, A., & Picaza, M. (2020). Exploring children's social and emotional representations of the Covid-19 pandemic. *Frontiers in Psychology, 11*, Article 1952. https://doi.org/10.3389/fpsyg.2020.01952

Inagaki, K., & Hatano, G. (1987). Young children's spontaneous personification as analogy. *Child Development, 58*(4), 1013–1020. https://doi.org/10.2307/1130542

Jammeh, A. L. J., Karegeya, C., & Ladage, S. (2023). Misconceptions on basic stoichiometry among the selected eleventh-grade students in the urban regions of the Gambia. *Journal of Baltic Science Education, 22*(2), 254–268. https://doi.org/10.33225/jbse/23.22.254

Kalish, C. W. (1996). Preschoolers' understanding of germs as invisible mechanisms. *Cognitive Development, 11*(1), 83–106. https://doi.org/10.1016/S0885-2014(96)90029-5

Karadon, H. D., & Şahin, N. (2010). Primary school students' basic knowledge, opinions and risk perceptions about microorganisms. *Procedia-Social and Behavioral Sciences,* 2(2), 4398–4401. https://doi.org/10.1016/j.sbspro.2010.03.700

Leonard, M. J., Kalinowski, S. T., & Andrews, T. C. (2014). Misconceptions yesterday, today, and tomorrow. *CBE—Life Sciences Education, 13*(2), 179–186. https://doi.org/10.1187/cbe.13-12-0244

Martinerie, L., Bernoux, D., Giovannini-Chami, L., & Fabre, A. (2021). Children's drawings of coronavirus. *Pediatrics, 148*(1), Article 2020047621. https://doi.org/10.1542/ peds.2020-047621

Maxwell, S. E. (1980). Pairwise multiple comparisons in repeated measures designs. *Journal of Educational Statistics, 5*(3), 269–287. https://doi.org/10.2307/1164969

McGellin, R. T. L., Grand, A., & Sullivan, M. (2021). Stop avoiding the inevitable: The effects of anthropomorphism in science writing for non-experts. *Public Understanding of Science, 30*(5), 621–640. https://doi.org/10.1177/0963662521991732

Milandri, M. (2004). Children's views of microbes: current beliefs about bacteria in Italian grade school children. *The Pediatric Infectious Disease Journal, 23*(12), 1077–1080. https://doi.org/10.1097/01.inf.0000145756.58944.f9

Nagy, M. H. (1953). The representation of "germs" by children. *The Pedagogical Seminary and Journal of Genetic Psychology, 83*(2), 227–240. https://doi.org/10.1080/08856559.1953.1053408

Nunnally, J. C. (1978). *Psychometric theory*. New York.

Pocsova, J., Mojzisova, A., Takac, M., & Klein, D. (2021). The impact of the COVID-19 pandemic on teaching mathematics and students' knowledge, skills, and grades. *Education Sciences, 11*(5), Article 225. https://doi.org/10.3390/educsci11050225

Prokop, P., & Fancovicova, J. (2006). Students' ideas about the human body: Do they really draw what they know?. *Journal of Baltic Science Education*, *10*(2), 86-95.

Prokop, P., Fancovicova, J., & Krajcovicova, A. (2016). Alternative conceptions about micro-organisms are influenced by experiences with disease in children. *Journal of Biological Education, 50*(1), 61–72. https://doi.org/10.1080/00219266.2014.1002521

Qekaj-Thaqi, A., & Thaqi, L. (2021). The importance of information and communication technologies (ICT) during the COVID-19—pandemic in case of Kosovo (analytical approach of students perspective). *Open Access Library Journal, 8*(7), 1–15. https://doi.org/10.4236/ oalib.1106996

Simon, U. K., Enzinger, S. M., & Fink, A. (2017). " The evil virus cell": Students 'knowledge and beliefs about viruses. *PLoS One, 12*(3), Article 0174402. https://doi.org/10.1371/journal.pone .0174402

Simonneaux, L. (2000). A study of pupils' conceptions and reasoning in connection with'microbes', as a contribution to research in biotechnology education. *International Journal of Science Education, 22*(6), 619–644. https://doi.org/10.1080/095006900289705

Stangier, U., Kananian, S., & Schüller, J. (2022). Perceived vulnerability to disease, knowledge about COVID-19, and changes in preventive behavior during lockdown in a German convenience sample. *Current Psychology, 41*, 7362–7370. https://doi.org/10.1007/s12144-021-01456-6

Sun, Z. (2019). A study on the educational use of statistical package for the social sciences. *International Journal of Frontiers in Engineering Technology, 1*(1), 20–29. https://doi.org/ 10.25236/IJFET.2019.010102

Tare, M., & Bendre, V. (2022). Gender and age differences in perceived vulnerability to disease and anxiety. *Journal of Psychosocial Research, 17*(1), 89–96. https://doi.org/10.32381/JPR.2022.17.01.8

Tinuola, F. R. (2016). Knowledge and beliefs about Ebola virus disease (EVD) among teachers in Ondo State Nigeria. *Mediterranean Journal of Social Sciences, 7*(3), 451–458. https://doi.org/10.5901/mjss.2016.v7n3p451

Walters, T., Simkiss, N. J., Snowden, R. J., & Gray, N. S. (2022). Secondary school students' perception of the online teaching experience during COVID-19: The impact on mental wellbeing and specific learning difficulties. *British Journal of Educational Psychology, 92*(3), 843–860. https://doi.org/10.1111/bjep.12475

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Waters, R., Carty, N., & Keller, C. C. (2023). The effect of drawing microbiology concepts on short-term retention before and after interrupted learning. *Medical Science Educator, 33*(5), 1205–1213. https://doi.org/10.1007/s40670-023-01879-9

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GIFTED STUDENTS' PERCEPTIONS ON SCIENCE COURSES IN GENERAL EDUCATION CLASSROOM

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Abstract. *Gifted students often experience different educational needs compared to their peers, especially in subjects like science. The aim of this study was to examine the perceptions of gifted students studying in primary school towards the science course. A phenomenological research method was used. The study group consisted of twenty-four gifted students aged 9–10 years studying in eleven different primary schools in a province in southeastern Türkiye during the 2023-2024 academic year. Data were collected through semi-structured interviews, which were conducted face-to-face. The data were analyzed using content analysis in the MAXQDA 24 software. Gifted students show a strong interest in astronomy, earth sciences, and chemistry, while their interest in other scientific fields, such as biology, is limited. They reported that science lessons often use teacher-centered, text-based approaches that offer limited technology active learning. Although science education at the Science and Art Center was satisfactory, the students expressed that regular classroom practices did not meet their expectations. Students emphasized the need for innovative teaching methods, active learning, laboratory activities, and outdoor learning opportunities. The findings indicate that teaching methods need to be improved, and student-centered approaches can enhance course quality and increase student motivation.*

Keywords: *gifted children, primary schools, qualitative approach, science courses*

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Introduction

Countries globally acknowledge the vital importance of education for national power and competitiveness. Substantial endeavors are underway in theoretical, applied, and policy research to cultivate gifted students across all disciplines. Countries allocate significant resources to invest in education and select students with extraordinary qualities who can benefit society. A range of programs is implemented to optimize the potential of these students. This educational strategy has emerged as a global priority. In Türkiye, Science and Art Centers (BILSEM) were founded in 2004, primarily in provincial centers, to implement enrichment programs that foster the scientific, artistic, social, and cultural growth of outstanding pupils. The implementation of an alternative enrichment program for gifted students constituted a positive development (Bildiren & Citil, 2021). Gifted individuals exist who are unable to participate in BILSEM programs due to factors such as transportation issues and difficulty with the identification process. They continue their education in conventional schools. In light of these deficiencies, the General Directorate of Special Education and Guidance Services established support education rooms in 2012 and executed several initiatives to cultivate the interests and skills of gifted students.

Countries have allocated special budgets and funds to the education of gifted students, aiming to maximize their talents and skills. These efforts have led to significant progress in national policies and transformations in education systems. Education programs aim to enable gifted students to realize their potential and progress in their areas of talent, taking into account individual differences (Reis & Renzulli, 2023; VanTassel-Baska & Wood, 2010). Curriculum differentiation, enrichment, acceleration, and rigor are the most prominent methods. These methods aim to address the cognitive and creative capacities of gifted students (Renzulli et al., 2010). In addition, strategies such as cooperative learning and flexible grouping are frequently used to support students' social and emotional development (Renzulli, 2012). Such practices not only increase academic achievement, but also improve students' critical thinking, problem solving and creative thinking skills (McCarthy, 2017). The programs emphasize the special educational needs of gifted students, supporting their self-actualization and progress in various areas of talent (Olszewski-Kubilius et al., 2024). In 1997, a document published by the NDE

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stated that "*the legal requirements for gifted education include accelerated learning, assignments and/or enrichment activities that are appropriate to students' abilities regardless of age or grade*" (p.56-57) and that changes to the existing curriculum were needed. The need for an in-depth and integrated process of exploration that goes beyond the curriculum in various programs is emphasized. This necessity has led to a diversity of practices across countries, as each education system is shaped by its own cultural context and educational policies. This diversity has therefore allowed for the sharing of best practices across the world, leading to enhanced support for gifted students.

Gifted Students and Science Education

From the earliest times, people have asked questions to understand nature and the universe: What is nature? How do natural phenomena occur? What is the origin of the universe? What paths should we follow to survive? These questions have formed the cornerstones of scientific thinking and have led people to develop research methods, problem-solving strategies and logical ways of thinking. Science, as part of this intellectual process, includes scientific tools such as induction, deduction, principles, laws and theories, and informs and deeply shapes many disciplines such as physics, chemistry, biology, astronomy, and Earth sciences (Tobin, 2016). While science is defined as the human endeavor to better know, recognize and make sense of the world (Zacharia, 2003), Thonney and Farrell (1995) have defined science as a systematic approach to understanding nature through observing, making inferences, testing ideas and using scientific thinking processes. Science covers a wide area, with an integrated structure that interacts with other fields (Tytler et al., 2021; Shaffer, 2011). This holistic structure shapes the purpose of science education aiming to raise science literate individuals who learn methods of scientific thinking, question and contribute to society with rational decisions (Holbrook & Rannikmae, 2007). Science teaching emphasizes skills such as predicting, observing, researching, hypothesizing and testing, and interpreting data to develop scientific process skills. Inquiry-based practices are frequently recommended to develop these skills, enabling students to develop scientific thinking while actively participating. Science education especially for gifted students, should provide environments that foster their creative and analytical thinking skills by presenting in-depth and complex problems. Gifted individuals need opportunities for higher levels of inquiry, discovery and innovative solutions. In this context, the potential of gifted students is maximized by implementing enriched programs and projects in science education (Park & Oliver, 2009; Winebrenner, 2000). In science curricula developed for gifted students, the importance of talent and career development activities is emphasized, innovative methods such as problem-based learning, STEM applications, blended learning, and flipped learning come to the fore (Nacaroglu & Bektas, 2023; Ozkan & Kettler, 2022; Robinson et al., 2014; Sternberg et al., 2022; Ulger & Cepni, 2020). Experts continue to work on integrating technology and artificial intelligence into gifted education and expanding their applications (Chen et al., 2013; David et al., 2023). Research has demonstrated the benefits of deepening activities with interdisciplinary studies, and integration models such as the engineering design cycle and STEM applications have been proposed (Bryan et al., 2016; Ouyang, & Xu, 2024; Sapounidis et al., 2024; Zhou et al., 2023). As a result, studies aim to ensure that gifted students progress not only cognitively in science but also in developing their non-cognitive characteristics (Olszewski-Kubilius, & Thomson, 2015; Renzulli, 2012).

There is a widespread view that standard science education practices do not provide an adequate foundation for gifted students to succeed in their areas of strength, enabling them to develop new skills (Taber, 2014). "*Flow*" is defined as a state in which these students are deeply focused on a task, forgetting the passage of time and thus being fully engaged. However, the extent to which this state of flow is experienced by gifted students in response to the requirements of the standard curriculum is still a matter of debate. While some experts argue that the traditional curriculum does not fully address the potential of these students and does not meet their need for deeper exploration (Bernal, 2003), others have explored how the curriculum can be adapted to their needs (Kaplan, 2009; Vantassel-Baska & Wood, 2010). Research shows that gifted individuals come to science classes more cognitively, affectively, and psychomotor ready than their peers (Gould et al., 2003; Ngoi & Vodracek, 2004; Tomlinson, 2001). Camcı Erdogan (2014) emphasized that gifted students have different characteristics in terms of interest, motivation, comprehension, and scientific inquiry, and that science teaching should be differentiated based on these characteristics. Differentiated science curriculum refers to the changes made to the content, process, learning products and environments in the science curriculum (Tomlinson, 2001). This type of curriculum provides more challenging, complex, and in-depth problem-solving opportunities for gifted students. For example, the science curriculum can be differentiated using the depth and complexity guidelines in the Grid model (Kaplan, 2009). This model encourages the effective use of higher order thinking skills by increasing the challenge of the content in the curriculum (Kaplan, 2009; Dodds, 2010). It also contributes to teachers' professional development by facilitating

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interdisciplinary connections and knowledge transfer in the curriculum (Grubb, 2011). It is also important to use universal themes in different areas and to broaden the scope of the curriculum to develop 21st century skills (Lauer, 2010; Park, 2008). For example, Kutlu Abu (2018) found that by differentiating the light and sound unit at the primary school level according to the theme of change and the Grid model's guidelines, this approach improved the self-regulation skills of gifted and other students. Camcı Erdoğan and Kahveci (2015) found that differentiating the Earth-Sun-Moon unit with the Parallel Curriculum Model and the Grid Model positively improved the attitudes of gifted middle school students towards science. The findings show that a differentiated science curriculum develops gifted students' interest and skills in science and enables them to learn more deeply.

In the literature, studies sampling gifted students have examined their perceptions across different educational practices and contexts. For example, black students' views on school (Ford & Harris, 1996), gifted students' views on summer programs and social support programs (Lee et al., 2015), perceptions of full-time grouping practices (Patry et al., 2001), and views on special classes (Vogl & Preckel, 2014) were examined. Simensen and Olsen (2024) stated that learning materials, activities, and peer interaction are limited in gifted students' mathematics classes and advanced needs are not met. Studies examining perceptions about science, on the other hand, usually involve gifted students at the middle or high school level (Ugulu, 2020). For example, Shin and Choi (2020) examined gifted middle school students' perceptions of the science curriculum and found that lessons using the science writing method had positive effects on inquiry, knowledge acquisition, learning enjoyment, and usefulness. However, studies show that the attitudes of gifted students towards science courses become less positive as they advance to higher grades (Egalite & Kisida, 2018; Swiatek & Lupkowski-Shoplik, 2000). Karnes and Riley (2005) stated that gifted students have a deep curiosity about science and enjoy problem-solving activities instead of repetition in lessons. In addition, gifted students dislike overgeneralized explanations and a lack of sufficient detail in science lessons (Han, 2007). Other studies have shown that gifted students find science lessons interesting and fun (Yang & Park, 2015). Gifted students, especially at the primary school level, generally have positive perceptions of science lessons. They have enthusiasm for science, show interest in science careers, and appreciate the social impact of science more than their average peers (Caleon & Subramaniam, 2008; Barrington & Hendricks, 1988). In addition, these students like to act like scientists, participate in group activities, and further explore challenging topics (Yang et al., 2014). They believe that science plays an important role in making the world a better place and improving living standards (Vitale & Johnson, 1988). Gifted students generally have a more positive attitude towards science and see science as an effective tool for improving the world and solving everyday problems (Sheldrake et al., 2017). However, the fact that gifted students have to live with this label, are in constant competition and face challenging tasks such as those in gifted education can sometimes negatively affect their attitudes towards science (Sak et al., 2015; Ugulu, 2020).

Studies have examined the perceptions of gifted students at the middle and high school levels on various topics such as perfectionism, mood, and multiple intelligences (Albright & Montgomery, 2023; Makkonen et al., 2022; Margot & Rinn, 2016; Milic & Simeunovic, 2024; Mofield & Peters, 2019; Portešová & Urbánek, 2013; Voitova et al., 2025). However, there is limited research on gifted students' perceptions of science courses at the elementary school level (Yang & Park, 2015). For example, Yang and Park (2015) examined gifted students' perceptions of laboratory-based science practices in elementary schools. The study found that students considered science lessons interesting. Teachers tended to recognize learning problems based on textbooks and general presentations. However, students wanted to learn by discussing learning problems directly during the experiment design phase. Urek and Dolu (2013) found that gifted students in grades 4 through 8 showed more interest in science than non-gifted students and that gifted girls were more interested in science than gifted boys and non-gifted girls. Ozdemir and Topalsan (2022) defined the metaphorical perceptions of gifted students regarding the science course as "positive", "association", and "challenging level". Akdag and Koksal (2022) found that eighth grade gifted students had high intrinsic motivation toward science. Koksal (2013) on the other hand, found that gifted students in the ninth grade had positive attitudes and motivation towards science.

Purpose and Importance

Addressing school experiences is an important issue in the multifaceted support of gifted students (Kang & Chung, 2012). School experiences provide information about various factors such as students' knowledge, perceptions, observations, practices and emotions. Therefore, identifying students' school experiences makes it

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possible to design enriched educational opportunities for their individual needs. Moreover, these experiences help educators understand the educational needs of gifted students and identify the challenges they face in the educational process. In the literature, gifted students' experiences are often limited to specialized courses, practices or curricular models. For example, middle and high school gifted students' experiences and perceptions of the Advanced International Certificate of Education (Hudson, 2019), University-Based Applications (Kang & Chung, 2012), the Gifted Program (Kitsantas et al., 2017), the Multidimensional Curriculum Models (Vidergor, 2020), and the "On-Going Topics" course (Patry et al., 2001) have been examined. However, studies on the school experiences of gifted students at the primary school level in regular schools are limited.

In particular, science-related experiences allow gifted students to develop in-depth research, inquiry and analytical thinking skills. In the literature, science-related experiences of gifted middle school students have been examined in special programs such as ASEAN +3 Junior Science Odyssey (Shin & Lee, 2023) and general programs (Kim et al., 2021). In addition, the experiences and skills of gifted students in STEM, as well as differentiation practices, and laboratory-based practices, have also been investigated (Kulegel & Topsakal, 2021; Park & Leon, 2011; Yang & Park, 2015). Koksal (2013) compared the motivation and attitudes of gifted and advanced gifted secondary schools towards learning science. There are few studies on the experiences of gifted students in regular primary classrooms in science courses. There is a need for an in-depth analysis of gifted students' conceptual perceptions of the science course in elementary schools, including their views on the methods, techniques, and practices used in the course. The aim of this study was to determine the perceptions of gifted students at the primary school level, regarding the science course. Gifted students' perceptions of science lessons in primary schools contribute to understanding the educational needs and developing teaching strategies. These insights can help design individualized and effective approaches to science education by providing information about how students approach lessons, the challenges they face and their learning styles. It can also provide guidance for diversifying teaching methods and making the best use of students' potential. The research sought to answer the following questions:

1. What are the conceptual perspectives of gifted primary school students about science courses?
2. What do gifted students think about the methods, techniques and practices used in science courses?
3. What are the difficulties that gifted primary school students experience in science courses?

Research Methodology

General Background

In this study, phenomenological research method was used to examine the perceptions of gifted students about science lessons. The main purpose of qualitative research is to describe in depth the experiences, feelings, thoughts, and meanings of individuals or groups rather than making generalizations about the population (Creswell 1998; Koopman, 2017; Merriam, 1998). The study aimed to understand the individual perceptions and experiences of gifted students about science lessons, and these experiences were described uniquely and in detail. In this context, the aim of the study is to contribute to the educational and curriculum development processes by examining the perceptions, feelings and thoughts of the students towards the science course.

Participants

Twenty-four gifted children, aged 9-10 years, were selected from 11 different primary schools in southeastern Türkiye. They were chosen based on their willingness to participate in the study, and parental permission was also obtained. Of these children, 9 are boys and 15 are girls, and all of them benefit from the support provided by BILSEM in addition to their regular schools. BILSEM offers special education programs, activities and resources aimed at maximizing the potential of gifted individuals. In the study, there are two main criteria for selecting participants: (i) attending primary school and (ii) being diagnosed as gifted. In this study, a criterion-based sampling method was used. Gifted students attending primary school have various strengths such as playing the piano, playing basketball, tennis and volleyball, painting, playing chess, experimenting, memorizing, and speaking English fluently. On the other hand, these students also have some weaknesses such as time management, study habits and social-emotional difficulties.

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Context

In the Turkish education system, gifted students are identified based on the recommendations of teachers and the evaluations of provincial and school guidance commissions. Students are examined using intelligence tests (general intellectual ability, art, music, etc.). These assessments are based on standardized test scores that take into account students' general intellectual abilities as well as their potential in special talent areas. The identification process is carried out through pre-assessment and individual tests. The students who participated in the study were those who were assessed by with the Anadolu-Sak Intelligence Scale (Sozel et al., 2018) and scored 130 or above on the IQ scale. The students included in the study were identified according to national criteria and were studying at BILSEM.

This research was conducted in a province in southeastern Türkiye with a population of approximately 300,000. Most schools in the region are public, and the province is largely rural. Rural schools may have fewer resources and infrastructure than urban schools. However, centers such as BILSEM offer an important opportunity to overcome these shortcomings. The occupations of families in this province are generally concentrated in trade, animal husbandry and the public sector (teaching, health, security). The economic situation of the students' families is good, and their educational attainment level is such that most have completed high school or university. These students are the children of families who recognize their special talents at an early age and make extra effort in this area. The gender distribution of the students was determined randomly, since student selection was based on voluntary participation.

Data Collection and Analysis

A semi-structured interview form, conducted through face-to-face interviews, was utilized as a data collection tool in this study. Semi-structured interview forms provide participants with a specific framework, while allowing them to express their thoughts more freely. This type of interview provides the opportunity to explore new themes or responses that may emerge during the research process, thus helping to obtain more comprehensive data. There are ten questions in the interview form. The questions aimed to determine the perceptions of gifted students on science lessons. Research permissions were obtained from the Ministry of National Education and the Ethics Committee for the interviews. The interviews were conducted face-to-face between 04.09.2023–and 20.09.2024. With the participants' permission, the interviews were audio-recorded, and each interview was conducted in a suitable, quiet classroom environment. Interviews were conducted on weekday afternoons according to the participants' availability, and each interview lasted approximately fifteen to twenty minutes. Participants were informed that the audio recording would be used for research purposes only. The data were analyzed using content analysis in the MAXQDA 24 program. The data obtained from the voice recordings were transcribed. The data and notes from the interviews were carefully analyzed to understand the experiences. Important meaning units in the data were coded. The themes were identified according to the similarities and differences in the codes. The analysis of themes led to different categories. Models and tables were used to represent the data.

Validity, Reliability and Ethics

In this study, various steps were taken to ensure validity and reliability. Validity was ensured through a data collection and analysis process appropriate to the purpose of the study. Face-to-face interviews were designed to understand the participants' experiences in depth, and open-ended questions were used. In this way, participants' perceptions and experiences were accurately reflected. The reliability of the data analysis was increased by calculating coder consistency. The inter-coder consistency coefficient was found to be 0.85, indicating that the consistency in the analysis process was high. In addition, the coding process was reviewed several times to ensure the accuracy of the data. Ethically, participants' rights were protected throughout the research process. Each individual participating in the study was informed about the purpose of the research and participated in the interviews on a voluntary basis. In addition, the confidentiality of the participants was protected, and the interviews were used for research purposes only. The research process was conducted in accordance with ethical rules and requirements, and the necessary permissions were obtained from the relevant institutions.

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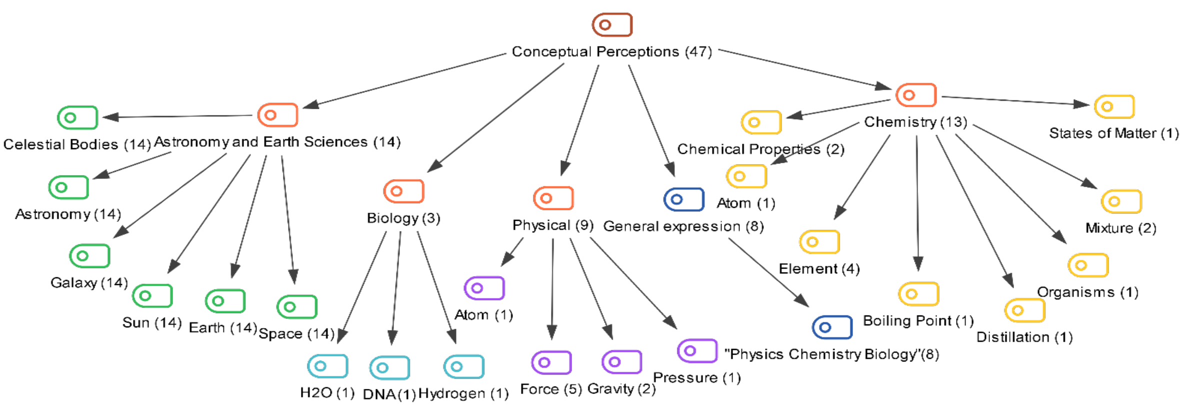
Research Results

When the research findings were evaluated holistically, four themes emerged regarding the perceptions of gifted students toward science courses. These themes are (i) conceptual perspectives of science courses, (ii) differentiated/enriched science activities, (iii) science materials and experiences, and (iv) expectations in science courses.

Conceptual Perspectives of Science

Students were first asked what concepts they associated with science. The answers given by the students were divided into two categories: basic concepts about science and sub-disciplines of science. The first basic concepts that came to their minds when science was mentioned were "*experiment, science, scientist, scientific method, invention, laboratory, microscope*". 18 gifted students repeated specifically the concept of experimentation. The discipline codes obtained when students take science courses are given in Figure 1.

Figure 1
Conceptual Perspectives of Gifted Students Towards Science



When the codes in Figure 1 were examined, 4 categories were reached: "physics, chemistry, and biology" group, astronomy sciences group, physics group, chemistry group, biology group. When the sub-codes related to the categories were examined, the frequencies within the astronomy category such as Space, Galaxies, Earth and Sun, were the highest *(f= 14)*.

> G6: [Space fascinates me and I find myself wondering about space because there is so much uncertainty. Mystery…]

There are 13 views that directly relate science to chemistry. When the subcodes of chemistry were examined, there were 9 chemistry codes, namely atom, boiling point, distillation, chemical properties, expansion, contraction, mixture and states of matter. A highly talented student, in relation to chemistry subjects, said the following:

> G16: [We conduct more chemistry experiments in applications. That's why when I think of science, I think more of chemistry.]

In the physics branch, where 9 people expressed their opinions, 4 codes were reached, namely force *(f= 5)*, gravity *(f= 2)*, atom *(f= 1)* and pressure *(f= 1)*. Three codes (DNA, H_2O, and Hydrogen) were identified in the biology branch. There are 8 talented students who can articulate the concepts of "physics, chemistry, and biology" together.

> G5: [When I think of science, I think of physics, chemistry and biology. I can't just say physics, chemistry or biology. (Why do you think so?) Because science is a big field, it is related to everything, it is hard to distinguish.]

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Differentiation/Enrichment Practices

Gifted students coded as G1, G5, G7, G8, G9, G10, G12 noted that enrichment or differentiation activities are rarely carried out in science lessons in regular schools. Many gifted students stated that enrichment/differentiation activities are conducted frequently in science classes in BILSEMs (G3, G6, G14, G17, G18, G20, G23, G24). They stated that prediction, observation, and reading activities are mostly included in regular classes. It was stated that teacher-centered and book-based experiments are conducted in science classes. They stated that materials such as beakers, water, different substances, microscopes, magnets, volumetric containers, test tubes, world models, and scales are used in teacher-centered experiments. Gifted students reported that they were not allowed to experiment on their own in regular schools and that they needed laboratories for experimentation.

> G10: [I like to do experiments, observe, and see what happens. But in science class, we listen, our teacher does not allow us to experiment on our own.]
>
> G18: [Normally, there are no different or enriched activities in the schools we go to. The teacher usually does the activities by reading from the book. They do the experiments themselves, and we watch or wait without doing anything.]
>
> G4: [I usually do research on my own to learn about the subjects.]
>
> G6: [We do research and observation.]
>
> G17: [If I know which experiment to do, I do the same experiment at home. I usually follow it from a textbook.]

While gifted students stated that different methods and techniques are frequently used in BILSEM applications when evaluating science lessons, they noted that such methods and techniques are not applied in normal classes. They stated that STEM, virtual trips, technology-based applications, artificial intelligence, coding and engineering applications are conducted in BILSEMs, and no technology-related application is conducted in normal classes.

> G13: [There is nothing related to technology in our school. There are projection devices, yes. They are only used for reflections for presentation purposes. For example, at BILSEM, we do activities such as STEM, robotic applications and engineering applications. We use computers effectively, we learn new things, such as how we can use artificial intelligence in our studies.]
>
> G22: [At BILSEMs, different applications are made in different fields such as physics, chemistry, biology, astronomy. We often do experiments. STEM applications are the applications that I enjoy working on.]

Science Materials and Experiences

Table 1 shows the coding of the most frequently used materials in science lessons and applications in experiments. Gifted students stated that they frequently used materials such as beakers, water, different substances, microscopes, magnets, volumetric flasks, test tubes, earth models and scales in science lessons. Fifteen gifted students stated that they generally followed the order in the textbook when conducting experiments. In the preparation phase of the experiments, 17 gifted students stated that teacher-centered experiments were conducted and that they participated in observation and estimation practices. Seven students reported that they searched the internet for information on the subject. The student identified as G7 stated that he did not prepare before the experiment. Student coded G7 said, "I do not prepare for the experiments because there are no difficult experiments. Experiments in schools are easier. There is no time to prepare for BILSEM experiments. I am tired when I go to BILSEM after school."

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Table 1
Experiences and Materials Used in Science Courses

Material Codes	Students	Frequency	Quotes
Water	G2*-G3-G6-G8-G9-G12-G20	7	"The most common material we use is water. We must pour it on the ground while using it. (G3)"
Microscope-Slide-Coverslip	G5-G23	1	"We made extensive use of water and glass because we are focusing on reflection. When using frosted glass, we must exercise caution because it has the potential to cut our hands... (G6)"
Beaker glass,	G7-G13-G14-G15-G16-G17-G19-G20-G23-G24	10	
Magnets	G1-G18-G21	3	"Different experimental materials such as beakers, heat sources, measuring tools and microscopes are generally used in experiments. (G23)"
Stone, sand	G13	1	
Volumetric Flask	G4-G10-G14-G23-G24	5	
Spirit Furnace Earth Globe Test Tube Scales, Thermometer Matters	G16 G18 G11-G16-G17-G21 G23-G24 G3-G5-G6-G10-G11-G15-G16- G17-G20-G21-G22-G24	1 1 3 2 12	
Experiment Preparation Stages	**Students**	**Frequency**	**Quotes**
Not knowing which experiment to do	G7	1	"Teachers do experiments themselves, we do not. At that stage, predictions are asked through question and answer. We observe as much as we can see.. (G6)"
Observation and prediction in teacher-centered experiments	G1, G6, G8, G9, G10, G12, G14, G15, G16, G17, G18, G19, G20, G21, G22, G23, G24	17	"If I know what experiment to do, I rehearse it at home. I usually follow it from a textbook. (G18)"
Reading a text about the experiment	G2, G3, G4, G6, G7, G10, G11, G12, G13, G14, G15, G18, G20, G21, G22	15	"I generally do research in order to gain knowledge about the subjects… (G4)"
Subject search on the internet	G4, G5, G10, G16, G18, G21, G22	7	

**G=Gifted student*

Expectations in Science Course

Table 2 shows the coding of perceptions of gifted students in the science course. There are nine sub-codes related to the problems experienced in science classes. These codes are failed experiments, technical malfunctions in materials, unwanted accidents, disciplinary problems in the classroom, finishing tasks early and feeling bored, too much noise, different pursuits, lack of materials and inadequate science knowledge. G1, G3, G4, G7, G9, G14, G15, G16, and G17 stated that they experienced a lack of materials in experiments. G4, G6, G8, G11, G12, and G13 perceive the unsuccessful results in experiments as a problem. G5, G7, G9, G21, and G22 stated that the tasks given in science class were finished early and they became bored during the lesson. Students with codes G1, G3, G7, G8, G18, and G20 stated that noise and discipline problems in the classrooms hindered the effectiveness of the lesson.

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Table 2
Gifted Perceptions Towards Science Lesson

Challenges Codes	Students	Frequency	Quotes
Failed Experiments	G4-G6-G8-G11-G12-G13	6	"There are many missing materials. Our teacher assigns tasks, such as instructing us to bring specific items. Occasionally, acquaintances may also fail to remember, and there will be a substantial amount of commotion. (G3)" "Indeed, there are instances when it is necessary to emit gas, such as the release of smoke or even an explosion. However, there are occasions when these expected outcomes fail to occur. (G6)" "Lack of materials or noise in the classroom. (G1)" "It appears that maintaining focus is more difficult for distracted students, as has often been observed in educational settings. I'm constantly distracted or bored. Because we stay for a long time, the teachers frequently warn the students to pay attention, as they have difficulty staying focused. (G15)"
Technical Malfunctions in Materials	G1-G10	2	
Unwanted Accidents	G2,G24	2	
Disciplinary Problems in the Classroom	G3, G18, G20	3	
Finishing Tasks Early and Feeling Bored	G5, G7, G9,G21,G22	5	
Too much Noise	G1, G3, G7, G8	4	
Different Pursuits	G2, G5, G10	3	
Lack of Materials	G1,G3, G4,G7, G9,G14, G15,G16,G17	9	
Lack of Information	G12, G19,G23	3	
Expectations from Science Class	**Students**	**Frequency**	**Quotes**
Enriched Methods and Techniques	G1,G6,G8,G10, G15	5	"I would like some topics, especially complex and challenging ones like force and motion, to be presented in a more comprehensive way. I would like to see activities where we are personally active to make hypotheses and design experiments, and make predictions. Not only I but also my classmates can become individually active. (G3)" "There is a lack of integration with technology in science classes. The use of different multimedia tools is not sufficient. (G14)"
Active Learning	G2, G3, G9, G12, G16,G20,G22	7	
Technology Integration	G4,G13,G14,G19,G23	5	
Cognitive-Social Activity/Outdoor Learning	G5-G7-G9,G18,G21,G24	6	
Student-centered Experiments	G3, G6, G11,G17	3	

When the given answers were examined, most of the students reported that science lessons should be based on active learning (f= 7), and should be supported with activities focused on skill development, including cognitive and social activities (f = 6). They interpreted an increase in the number of cognitive and social activities (outside school learning) in science lessons as an important factor in their self-actualization. G21 said, "For example, I am interested in birds. I like to read about this subject. There are no social practices in schools. We should go birdwatching, get together with friends, and go on a trip." G24 said, "Sometimes it would be great to have a trip outside school focused on science subjects and research design. It would be useful if our observations were related to real life, and we could work with our friends. What would be the benefit? We would understand difficult subjects better. We would have the opportunity to do research in different places." The opinions highlighted the importance of integrating science lessons with technology and multimedia tools. G13 said, "Only presentations are used for the subjects we study in science classes. Interactive, technology-based applications are not implemented in normal schools. When we come to BILSEM, we can encounter different applications such as coding." Regarding these views, student-centered activities should be implemented in science applications and the use of enriched methods and techniques should be increased. G10 said, "We should do experiments ourselves and undertake projects. We do projects. For example, I went to courses: STEM and robotic coding. We can engage in activities like these."

Discussion

In this study, the perceptions of gifted students in primary schools towards science courses were examined in depth. The research themes are a conceptual perspective of the science course, differentiated/enriched science

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activities, science materials and experiences, and expectations from the science course. Most gifted students associate the concept of science with astronomy and Earth sciences. They stated that they have special interests in space, galaxies, Earth, Sun and celestial bodies. When the relevant literature is examined, it reveals that gifted children have a high interest in astronomy and earth sciences and enjoy doing research and reading on these subjects (Onal & Onal, 2021). Karabulut (2014) reported that gifted individuals have been studying astronomy and earth sciences from the past to the present, that they have special interests and that these subjects are given two hours per week in science high schools. Although astronomy and earth sciences are the oldest sciences that enable people to understand their place in the universe and the natural events happening around them, they are underrepresented in the broader context of contemporary sciences (Trumper, 2006). Many laws taught in school courses naturally apply to universal phenomena, illustrating their broad applicability. It is the duty of astronomers to understand and interpret the functioning of this laboratory (Hudgins, et al., 2006). Therefore, it is considered beneficial that gifted students have an interest in this field of science. The reason for this finding may be that there are many uncertainties and mysteries related to astronomy and earth sciences, the desire to discover these subjects may have attracted students to explore these fields. In addition, situations such as talking about astronomy with family and peers and the emphasis on astronomy in science fiction movies may have increased the interest of gifted students in astronomy and earth sciences (Richards & Kelly, 2024; Susman & Pavlin, 2020). Subası et al. (2015) conducted a study on the perspectives of gifted students on astronomy and space sciences. In this study, they found that the disciplines of astronomy and Earth Sciences generally involve the use of hypothetical thinking and analytical thinking. Studies have shown that the use of augmented virtual reality technologies increases students' interest in and attitudes towards astronomy concepts (Onal & Onal, 2021; Aktas, 2023).

When science was mentioned, most gifted students first associated it with astronomy, although more subcodes focused on chemistry. When the subcodes were examined, there were fourteen codes for astronomy and thirteen codes for chemistry. The findings show that gifted students associated the science course more with their experiences in chemistry. This may indicate that applications related to chemistry were carried out more often in science courses. Indeed, the student with the code G16 stated that chemistry experiments were frequently carried out and that he directly associated chemistry with science courses. Based on the findings, most of the gifted students were interested in astronomy and earth sciences, but they perceived that chemistry applications were carried out more in normal classes. Indeed, when asked which materials were used in science courses, most students reported that the tools and equipment frequently used in chemistry experiments in the laboratory were indicative of common resources accessed by students. Chemistry subjects are generally supported by laboratory experiments. Although there is no laboratory in every primary and secondary school in Türkiye, teachers try to provide science education to children using their own resources. Having access to simple tools and equipment may have led teachers to conduct more experiments in chemistry. When the 2024 science curriculum in Türkiye is examined, themes related to all sub-branches of science are evident: scientific process skills, self-regulation, communication, and social emotional learning skills such as cooperation, are at the forefront rather than the emphasis on science fields. Taber (2014) reported that chemistry has an abstract and challenging nature and that enrichment based on complex, open-ended, task-oriented laboratory practices would be beneficial for gifted children.

Gifted students stated that differentiated activities were rarely used in regular science classes. However, they considered enrichment activities to be sufficient in BILSEM applications. Watters and Diezmann (2003) stated that science teachers rarely provided gifted students with enrichment opportunities within formal school structures. They reported that school problems were disconnected from world problems. Teachers' epistemological beliefs and the notable tendency towards rote learning, based on discipline had an effect on many students, which produced quite negative attitudes towards science (Watters & Diezmann, 2003). This finding aligns with most studies indicating that differentiation was rarely used for gifted students in regular classes (Archambault et al., 1993; Bernal, 2003; Westberg et al., 1993). VanTassel-Baska et al. (2021) found that gifted students did not generally benefit sufficiently from differentiation practices; middle school classes were less effective than elementary or high schools in using differentiation for gifted students. In 38 studies on differentiation, Nicholas et al. (2024) found that gifted, high-ability, high-performance students preferred interdisciplinary or intercurricular integrated learning experiences, and disciplinary areas such as engineering, science, analogies, and scales. The reason for this finding in the study may be that teachers' knowledge and practices regarding differentiation are insufficient, and their self-efficacy levels for differentiation are potentially low. Caldwell (2012) developed a regression model on differentiated instruction, attitudes, and self-efficacy in the education of gifted students in regular classes, revealing that these three variables interact. This study found that teacher self-efficacy was a more important factor than attitudes toward gifted students in voluntarily differentiating education for gifted students (Caldwell, 2012).

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The majority of gifted students stated that they used observation, prediction, and online research during experiments. Gifted students generally reported that they followed the order in the textbook and that the activities were teacher-centered. However, students stated that there were various problems in science classes such as missing materials, completing tasks early, getting bored, experiments failing, lack of content knowledge among teachers, noise, and discipline problems in the classroom. According to gifted students, insufficient technical materials, technical malfunctions, and unintended accidents are among the problems related to the course. Kruit et al. (2018) emphasized that suitable environments and materials should be available for the successful application of the experimental method in science, and that it is important to have qualified teachers who follow scientific practices. VanTassel-Baska (2021) stated that the lack of emphasis on visual arts, mechanical arts, and technology for gifted students led to boredom in a classroom full of words. Yang and Park (2015) found that gifted students perceived that experimental design in science classes was teacher-centered, textbook-focused, and not student-centered. An examination of the relevant literature shows that lessons taught in fields such as science and mathematics without differentiation are boring for students, resulting in tasks being completed early (Hofer, 2023; Groman, 2023; VanTassel-Baska, & Brown, 2021). Johnsen (2023) reported that educators need to learn how to create inclusive, effective learning environments that are sensitive, engaging and encourage interaction. Jeong and Kang (2022) have shown that if the interests of gifted students are supported in effective science teaching, these students develop better explanation and understanding skills in science subjects. An effective learning environment is not static, but a dynamic area that addresses the interests, strengths and needs of each student. The findings obtained from the study may include reasons such as teachers not applying preventive classroom management, a lack of knowledge on this subject and the unmet needs of gifted students in science. In Türkiye, studies are ongoing to provide teachers with an inclusive education approach and a differentiated philosophy that integrates with the National Education Maarif Model (2023).

Gifted students' expectations of science classes include student-centered experiments based on active learning, along with out-of-school learning environments to develop cognitive and social skills. In addition, integrating technology into classes and using innovative methods and techniques are among other expectations. In science education, issues such as making a transition from theory to practice, designing student-centered experiments, working with real-life problems, and using different methods and techniques supported by technology are considered essential. Nacaroglu and Bektas (2023) revealed that the flipped classroom model for gifted students in science classes positively affected students' self-regulated learning and academic success. O'Grady-Jones and Grant (2023) revealed that Collaborative Game Design-Based Learning on 21st Century Skills had a positive effect on gifted students' problem-solving, creativity, and collaboration. Yoon et al. (2020) emphasized the importance of developing enrichment programs to foster gifted and talented students' strong leadership skills, scientific knowledge, and articulate visions for the future. Sak and Ayas (2020) found that gifted students produced more creative hypotheses about scientific facts, designed more effective experiments to test hypotheses, and evaluated scientific evidence more effectively after participating in The Education Programs for Talented Students (EPTS). Ozdeniz et al. (2023) found that blended learning applications in science classes improved gifted students' scientific reasoning and scientific process skills.

Conclusions and Implications

The findings of this study reveal the perceptions of gifted students in primary school towards science lessons. Gifted students generally associate the concept of science with elements such as experiment, scientific method, laboratory and microscope, and are particularly interested in astronomy, earth sciences and chemistry. However, it was found that interest in other areas of science, such as biology, was quite limited. This situation shows that the scope of science should be expanded and focus more on areas such as biology. The reason for this finding may be that schools in the southeastern Türkiye are not equipped with laboratories that include microscope facilities. In addition, these students do not adequately establish the relationship between science concepts and technology. This situation indicates a need to enhance the integration of science education with technology, particularly through interdisciplinary applications such as STEM.

Gifted students stated that they generally encountered teacher-centered practices in science lessons and that technology and student-centered learning methods were insufficient. The lack of technology-based practices such as STEM, robotic coding and engineering negatively diminishes the interest of these students in science lessons and limits their development potential. While the students found the science education they received in BILSEMs more satisfactory, they stated that the practices offered in regular classrooms were not in line with their expectations. In

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science courses, student-centered and active learning-based experiments are important factors that contribute to the development of students' cognitive and social skills. In this context, ensuring the transition from teacher-centered approaches to student-centered approaches improves the quality of the course and increases students' motivation. In addition, increasing technology integration into science lessons, implementing differentiated teaching models and enriching out-of-school learning opportunities play an important role in meeting students' expectations. In order for gifted students attending primary school to achieve the goals expected of science education, it is clear that some revisions should be made in the current curriculum. Inclusion of innovative teaching methods such as flipped classrooms, blended learning, and approaches that develop skills such as problem solving, creativity, and collaboration in science lessons would be an important step to meet the educational needs of these students. In addition, integrating cognitive and non-cognitive elements, such as self-regulation skills, into science education can contribute to students' self-actualization. The implementation of such an educational approach is expected to enable students to participate more actively in learning and may provide a more productive science education experience.

Limitations

Among the limitations of this study is that the participant group was limited to gifted students in a specific region making it difficult to generalize the results to all gifted students. In addition, the exclusive use of interviews was a limitation in data collection. In future studies, the use of observations in science lessons may increase the depth of the findings by providing a more diverse array of data. The evaluations on teaching methods and technology integration in science lessons were based only on students' perceptions, and the perspectives of teachers or school administrators were ignored. Finally, only students' views prevented a definitive assessment of how effective the proposed changes would be in the classroom environment.

Note

Some of the findings in this study were presented at the *8th National Congress on Education of the Gifted* held in Ankara from 2 to 4 November 2023.

Declaration of Interest

The authors declare no competing interest.

References

Akdag, E., & Koksal, M. S. (2022). Investigating the relationship of gifted students' perceptions regarding science learning environment and motivation for science learning with their intellectual risk taking and science achievement. *Science Education International*, *33*(1), 5–17. https://doi.org/10.33828/sei.v33.i1.1

Aktas, A. (2023). *The effect of augmented reality supported instructional activities on gifted students 'attitudes towards astronomy* (Master›s thesis). Middle East Technical University, Türkiye. https://open.metu.edu.tr/handle/11511/106021

Albright, E. A., & Montgomery, D. (2023). Perceptions of the emotional self for adolescents who are gifted. *Roeper Review*, *45*(1), 6–20. https://doi.org/10.1080/02783193.2022.2145399

Archambault, F. X., Brown, S., Hallmark, B. W., Zhang, W., & Emmons, C. (1993). Regular classroom practices with gifted students: Results of a national survey of classroom teachers. *The National Research Center on the Gifted and Talented, The University of Connecticut*, Storrs, Connecticut.

Barrington, B., & Hendricks, B. (1988). Attitudes toward science and science knowledge of intellectually gifted and average students in third, seventh, and eleventh grades. *Journal of Research in Science Teaching, 25*, 679–687. https://doi.org/10.1002/TEA.3660250806

Bernal, E. M. (2003). To no longer educate the gifted: Programming for gifted students beyond the era of inclusionism, *Gifted Child Quarterly, 47*(3), 183–191. http://dx.doi.org/10.1177/001698620304700302

Bildiren, A., & Citil, M. (2021). Educating gifted children in Turkey: A retrospective analysis and the current state. *International Journal of Educational Reform, 31*(3), 278–299. https://doi.org/10.1177/10567879211050345

Bryan A., & Volchenkova K. N. (2016). Blended learning: Definition, models, implications for higher education. *Bulletin of the South Ural State University. Ser. Education. Educational Sciences, 8*(2), 24–30. https://doi.org/10.14529/ped160204

Caldwell, D. W. (2012). Educating gifted students in the regular classroom: Efficacy, attitudes, and differentiation of instruction. *Electronic Theses and Dissertations*. https://digitalcommons.georgiasouthern.edu/etd/822

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Camcı Erdogan, P. (2014). *Bilimsel yaratıcılığı temel alan farklılaştırılmış fen ve teknoloji öğretiminin üstün zekalı ve yetenekli öğrencilerin başarı, tutum ve yaratıcılığına etkisi* [The effect of differentiated science and technology instruction based on scientific creativity on gifted and talented students' achievement, attitude and creativity] (Unpublished doctoral dissertation). Istanbul University, Türkiye.

Camcı Erdogan, S., & Kahveci, N. G. (2015). The effect of different science and technology education on the courses of gifted and talented students. *Hasan Ali Yücel Journal of Faculty of Education*, *12*(1), 191–207. https://dergipark.org.tr/tr/pub/iuhayefd/issue/8802/110037

Caleon, I., & Subramaniam, R. (2008). Attitudes towards science of intellectually gifted and mainstream upper primary students in Singapore. *Journal of Research in Science Teaching*, *45*, 940–954. https://doi.org/10.1002/TEA.20250

Chen, J., Yun Dai, D., & Zhou, Y. (2013). Enable, enhance, and transform: How technology use can improve gifted education. *Roeper Review*, *35*(3), 166–176. http://dx.doi.org/10.1080/02783193.2013.794892

Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions.* Sage.

David, A., Kiose, V., Maikou, A., Tzelepi, E., & Stathopoulou, A. (2023). The impact of ICTs (Robotics, VR, AI, games) on gifted students' education. *Eximia*, *8*, 31–50. https://www.eximiajournal.com/index.php/eximia/article/view/240

Dodds, K. M. (2010). *Effects of the prompts of depth and complexity on gifted and non–gifted students.* (Unpublished doctoral thesis). University of Southern California, Los Angeles.

Egalite, A. J., & Kisida, B. (2018). The effects of teacher match on students' academic perceptions and attitudes. *Educational Evaluation and Policy Analysis*, *40*(1), 59–81. https://doi.org/10.3102/0162373717714056

Ford, D., & Harris, J. (1996). Perceptions and attitudes of black students toward school, achievement, and other educational variables. *Child Development*, *67(*3), 1141–1152. https://doi.org/10.1111/J.1467–8624.1996.TB01787.X

Gould, J. C., Weeks, V., & Evans, S. (2003). Science starts early. *Gifted Child Today*, *26*(3), 38–65. https://doi.org/10.4219/gct–2003–102

Grubb, R. C. (2011). *The relationship between the implementation of a differentiated curriculum and the development of intellectualism* (Unpublished doctoral thesis), University of Southern California, Los Angeles.

Han, K. S. (2007). The possibilities and limitations of gifted education in Korea: A look at the ISEP science-gifted education center. *Asia Pacific Education Review*, *8*, 450–463.

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education*, *29*(11), 1347–1362. https://doi.org/10.1080/09500690601007549

Hudgins, D. W., Prather, E. E., Grayson, D. J., & Smits, D. P. (2006). Effectiveness of collaborative ranking tasks on student understanding of key astronomy concepts. *Astronomy Education Review*, *5*(1), 1–22. https://doi.org/10.3847/AER2006001

Hudson, K. (2019). *Differences between gifted and non-gifted students' perceptions of advanced international certificate of education course quality* (Unpublished doctoral thesis), Liberty University, Virginia.

Jeong, J., & Kang, H. (2022). Analysis on types of scientific emoticon made by science-gifted elementary school students and their perceptions on making scientific emoticons. *Journal of the Korean Association for Science Education*, *42*(3), 311–324. https://doi.org/10.14697/jkase.2022.42.3.311

Kang, K., & Chung, C. (2012). The perception of scientifically gifted students of a university-affiliated gifted education center toward its educational programs. *Journal of The Korean Association For Science Education,* 32, 751–759. https://doi.org/10.14697/JKASE.2012.32.4.751

Kaplan, S. N. (2009). The grid: A Model to construct differentiated curriculum for the gifted. In J. S. Renzulli, E. J. Gubbins, K. S. McMillen, R. D. Erkert ve C. A. Little (Eds.), *Systems and Models for Developing Programs for the Gifted and Talented* (pp. 235–253) Mansfield Center, CT: Creative Learning Press.

Karabulut, R. (2014). A model proposal in gifted children: Club study in science house, *Erciyes University Journal of Institute of Social Sciences*, *37*(2), 61–69. https://dergipark.org.tr/en/pub/erusosbilder/issue/23771/253404

Karnes, F. A., & Riley, T. L. (2005). *Competitions for talented kids*. Prufrock Press.

Kim, T., Kwak, Y., & Park, W. (2021). Comparison on positive experiences about science between gifted and general students in middle school. *Journal of the Korean Earth Science Society*, *42*(4), 459–469. https://doi.org/10.5467/jkess.2021.42.4.459

Kitsantas, A., Bland, L., & Chirinos, D. (2017). Gifted students' perceptions of gifted programs: An inquiry into their academic and social-emotional functioning. *Journal for the Education of the Gifted*, *40*, 266–288. https://doi.org/10.1177/0162353217717033

Koksal, M. S. (2013). Comparison of gifted and advanced students on motivation toward science learning and attitude toward science. *Journal of the American Academy of Special Education Professionals*, *100*, 112.

Koopman, O. (2017). Phenomenology as a method in education research. *Science education and curriculum in South Africa*, 1–24. https://doi.org/10.1007/978–3–319–40766–1_1

Kulegel, S., & Topsakal, U. (2021). Investigating perceptions and skills of gifted students in STEM education. *World Journal of Education*, *11*(3), 39–46. https://doi.org/10.5430/wje.v11n3p39

Kutlu Abu, N. (2018). *For the inclusion of gifted students' evaluation of differentiated science activities*. (Doctoral thesis), Amasya University, Amasya, Türkiye.

Kruit, P. M., Oostdam, R. J., Van den Berg, E., & Schuitema, J. A. (2018). Assessing students' ability in performing scientific inquiry: Instruments for measuring science skills in primary education. *Research in Science & Technological Education*, *36*(4), 413–439. https://doi.org/10.1080/02635143.2017.1421530

Lauer, J. L. (2010). *Experts' perspectives on the application and relevancy of depth and complexity to academic disciplines of study* (Doctoral thesis), University of Southern California, Los Angeles, US.

Lee, S., Olszewski–Kubilius, P., Makel, M., & Putallaz, M. (2015). Gifted students' perceptions of an accelerated summer program and social support. *Gifted Child Quarterly*, *59*, 265–282. https://doi.org/10.1177/0016986215599205

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Makkonen, T., Lavonen, J., & Tirri, K. (2022). Factors that help or hinder the development of talent in physics: A qualitative study of gifted Finnish upper secondary school students. *Journal of Advanced Academics*, *33*(4), 507–539. https://doi.org/10.1177/1932202X221111828

Margot, K. C., & Rinn, A. N. (2016). Perfectionism in gifted adolescents: A replication and extension. *Journal of Advanced Academics*, *27*(3), 190–209. https://doi.org/10.1177/1932202X16656452

Merriam, S. B. (1998). *Qualitative research and case study applications in education* (Second edition). Jossey–Bass Publishers.

Milic, S., & Simeunovic, V. (2024). Do gender stereotypes play a role in the process of identifying gifted students in Western Balkan countries? Case study Bosnia and Herzegovina. *European Journal of Education*, *59*(2), 1–23. https://doi.org/10.1111/ejed.12594

Mofield, E., & Parker Peters, M. (2019). Understanding underachievement: Mindset, perfectionism, and achievement attitudes among gifted students. *Journal for the Education of the Gifted*, *42*(2), 107–134. https://doi.org/10.1177/0162353219836737

McCarthy, J. (2017). *So all can learn: A practical guide to differentiation*. Rowman & Littlefield.

Nacaroglu, O., & Bektas, O. (2023). The effect of the flipped classroom model on gifted students' self–regulation skills and academic achievement. *Thinking Skills and Creativity, 47,* 1–18. https://doi.org/10.1016/j.tsc.2023.101244

National Education Maarif Model (2023). https://tymm.meb.gov.tr/

NDE (1997). Promising Curriculum and Instructional Practices for High–Ability Learners Manual, Nebraska Depertment of Education. www.nde.state.ne.us

Ngoi, M., & Vondracek, M. (2004). Working with gifted science students in a public high school environment: One school's approach. *Journal of Secondary Gifted Education*, *15*(4), 141–147. https://doi.org/10.4219/jsge–2004–459

O'Grady-Jones, M., & Grant, M. M. (2023). Ready coder one: collaborative game design–based learning on gifted fourth graders' 21st century skills. *Gifted Child Today*, *46*(2), 84–107. https://doi.org/10.1177/10762175221149259

Olszewski-Kubilius, P., Subotnik, R. F., Worrell, F. C., Assouline, S. G., Stoeger, H., & Ziegler, A. (2024). Extending research on psychosocial skills and appropriate instruction in developing talents. *Journal for the Education of the Gifted*, *47*(4), 335–339. https://doi.org/10.1177/01623532241281566

Olszewski-Kubilius, P. & Thomson, D. (2015). Talent development as a framework for gifted education, *Gifted Child Today, 38*(1), 49–59. https://doi.org/10.1177/1076217514556531

Onal, N. T., & Onal, N. (2021). The effect of augmented reality on the astronomy achievement and interest level of gifted students. *Education and Information Technologies*, *26*(4), 4573–4599. https://doi.org/10.1007/s10639–021–10474–7

Ozdemir, D., & Kinik Topalsan, A. (2022). Metaphorical perceptions of gifted students towards mathematics and science concepts. *Educational Process: International Journal*, *11*(3), 97–121. https://doi.org/10.22521/edupij.2022.113.6

Ozdeniz, Y., Aktamıs, H., & Bildiren, A. (2023). The effect of differentiated science module application on the scientific reasoning and scientific process skills of gifted students in a blended learning environment. *International Journal of Science Education*, *45*(10), 827–849. https://doi.org/10.1080/09500693.2023.2175627

Ozkan, F., & Kettler, T. (2022). Effects of STEM education on the academic success and social–emotional development of gifted students. *Journal of Gifted Education and Creativity, 9*(2), 143–163.

Ouyang, F., & Xu, W. (2024). The effects of educational robotics in STEM education: A multilevel meta-analysis. *International Journal of STEM Education*, *11*(1), 7. https://doi.org/10.1186/s40594–024–00469–4

Park, M. A. (2008). *Factors affecting the transfer of differentiated curriculum from professional development into classroom practice* (Unpublished doctoral thesis), University Southern California, Los Angeles, US.

Park, M. J., & Jeon, D. R. (2011). Gifted students' differentiated experiences in science classes. *Journal of Gifted/Talented Education*, *21*(2), 531–546. https://doi.org/10.9722/JGTE.2011.21.2.531

Park, S., & Steve Oliver, J. (2009). The translation of teachers' understanding of gifted students into instructional strategies for teaching science. *Journal of Science Teacher Education*, *20*, 333–351. https://doi.org/10.1007/s10972–009–9138–7

Patry, J. L., Weyringer, S., & Wageneder, G. (2001). Gifted students' perception of special courses (On–going topics). *Academic Exchange Quarterly*, *5*(3), 155–163. https://doi.org/10.1177/2156759X0801200214

Portešová, Š., & Urbánek, T. (2013). Typology of perfectionism in a group of mathematically gifted Czech adolescents over one decade. *The Journal of Early Adolescence*, *33*(8), 1116–1144. https://doi.org/10.1177/0272431613487603

Renzulli, J. S. (2012). Reexamining the role of gifted education and talent development for the 21st century: A four–part theoretical approach. *Gifted Child Quarterly*, *56*(3), 150–159. https://doi.org/10.1177/0016986212444901

Renzulli, J. S., Gubbins, J. E., McMillan, K. S., Eckert, R. D., Little, C. A. & Vidergor, H. (2010) Systems and models for developing programs for the gifted and talented. *Gifted and Talented International, 25*(2), 171–172. https://doi.org/10.1080/15332276.2010.11673581

Reis, S. M., & Renzulli, J. S. (2023). The schoolwide enrichment model: A focus on student strengths & interests. In *Systems and models for developing programs for the gifted and talented* (pp. 323–352). Routledge.

Richards, Z., & Kelly, A. (2024). Astronomy identity framework for undergraduate students and researchers. *arXiv preprint arXiv:2410.00885*. https://doi.org/10.48550/arXiv.2410.00885

Robinson, A., Dailey, D., Hughes, G., & Cotabish, A. (2014). The effects of a science–focused STEM I–intervention on gifted elementary students' science knowledge and skills. *Journal of Advanced Academics*, *25,* 189– 213. https://doi.org/10.1177/1932202X14533799

Sak, U., Ayas, M. B., Sezerel, B. B., Opengin, E., Ozdemir, N. N., & Gürbüz, S. D. (2015). Gifted and talented education in Türkiye: Critics and prospects. *Talent*, *5*(2), 110–132. https://theeducationjournals.com/index.php/talent/article/view/38

Sak, U., & Ayas, B. (2020). EPTS curriculum model: Optimum curriculum differentiator for the education of gifted students. *Gifted Education International*, *36*(2), 154–169. https://doi.org/10.1177/0261429420917879

Sapounidis, T., Tselegkaridis, S., & Stamovlasis, D. (2024). Educational robotics and STEM in primary education: A review and a meta-analysis. *Journal of Research on Technology in Education*, *56*(4), 462–476. https://doi.org/10.1080/15391523.2022.2160394

https://doi.org/10.33225/jbse/25.24.296

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

Sozel, H. K., Opengin, E., Sak, U., & Karabacak, F. (2018). The discriminant validity of the Anadolu-Sak Intelligence Scale (ASIS) for gifted and other special education groups. *Turkish Journal of Giftedness and Education*, *8*(2), 160-180.

Subasi, M., Aydin, S., & Kocak, G. (2015). Gifted students' perceptions on basic astronomy concepts. *Journal of Emerging Trends in Educational Research and Policy Studies*, *6*(6), 444–451.

Susman, K., & Pavlin, J. (2020). Improvements in teachers' knowledge and understanding of basic astronomy concepts through didactic games. *Journal of Baltic Science Education*, *19*(6), 1020–1033. https://doi.org/10.33225/jbse/20.19.1020

Shaffer, D. (2011). *The effects of differentiated instruction on grade 7 math and science scores*. (Doctoral Dissertation), Walden University, Minneapolis, USA.

Sheldrake, R., Mujtaba, T., & Reiss, M. (2017). Science teaching and students' attitudes and aspirations: The importance of conveying the applications and relevance of science. *International Journal of Educational Research*, *85,* 167–183. https://doi.org/10.1016/J.IJER.2017.08.002

Shin, C., & Lee, S. (2023). Analysis of science-related experiences and changes in perceptions of science of middle school gifted students who participated in ASEAN+3 junior science odyssey. *Korean Science Education Society for the Gifted*, 12–27. https://doi.org/10.29306/jseg.2023.15.1.12

Shin, E., & Choi, W. (2020). Middle school science gifted students' perceptions of the effectiveness of science classes using science writing heuristic. *Journal of the Korean Chemical Society, 64,* 277–290. https://doi.org/10.5012/JKCS.2020.64.5.277

Simensen, A. M., & Olsen, M. H. (2024). Gifted students' actualization of a rich task's mathematical potential when working in small groups. *Education Sciences*, *14*(2), 151-167. https://doi.org/10.3390/educsci14020151

Sternberg, R., Ehsan, H., & Ghahremani, M. (2022). Levels of teaching science to gifted students. *Roeper Review*, *44,* 198–211. https://doi.org/10.1080/02783193.2022.2115178

Swiatek, M. A., & Lupkowski–Shoplik, A. (2000). Gender differences in academic attitudes among gifted elementary school students. *Journal for the Education of the Gifted*, *23*(4), 360–377. https://doi.org/10.1177/016235320002300403

Taber, K. S. (2014). *Student thinking and learning in science: Perspectives on the nature and development of learners' ideas*. Routledge.

Thonney, P. F., & Farrell, T. J. (1995). *In the bag!*. Cornell Cooperative Extension.

Tobin, K. (2016). Collaborating on global priorities: Science education for everyone–any time and everywhere. *Cultural Studies of Science Education*, *11*, 27–40. https://doi.org/10.1007/s11422–015–9708–2

Tomlinson, C. A. (2001). How to differentiate instruction in mixed–ability classrooms. Pearson Education.

Trumper, R. (2006). Teaching future teachers basic astronomy concepts, seasonal changes, at a time of reform in science education. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *43*(9), 879–906. https://doi.org/10.1002/tea.20138

Tytler, R., Mulligan, J., Prain, V., White, P., Xu, L., Kirk, M., ... & Speldewinde, C. (2021). An interdisciplinary approach to primary school mathematics and science learning. *International Journal of Science Education*, *43*(12), 1926–1949. https://doi.org/10.1080/09500693.2021.1946727

Ugulu, I. (2020). Gifted students' attitudes towards science. *International Journal of Educational Sciences*, *28*(1–3), 7–14. http://dx.doi.org/10.31901/24566322.2020/28.1–3.1088

Ulger, B., & Cepni, S. (2020). Gifted education and STEM: A thematic review. *Journal of Turkish Science Education*, *17*(3), 443–466. https://doi.org/10.36681/tused.2020.38

Urek, H., & Dolu, G. (2013). Approaches of intellectually gifted and non–gifted students towards the science course. *Journal of Gifted Education Research*, *1*(3), 184–198.

VanTassel–Baska, J. & Wood, S. (2010). The Integrated Curriculum Model (ICM), *Learning and Individual Differences*, *20,* 345–357. https://doi.org/10.1016/j.lindif.2009.12.006

VanTassel–Baska, J., & Brown, E. F. (2021). An analysis of gifted education curriculum models. *Methods and Materials for Teaching the Gifted*, 107–138. http://dx.doi.org/10.4324/9781003236603–7

VanTassel–Baska, J., Hubbard, G. F., & Robbins, J. I. (2021). Differentiation of instruction for gifted learners: Collated evaluative studies of teacher classroom practices. *Springer International Handbooks of Education*, 945–979. https://doi.org/10.1007/978–981–13–3041–4_45

VanTassel–Baska, J. (2021). Curriculum in gifted education: The core of the enterprise. *Gifted Child Today*, *44*(1), 44–47. https://doi.org/10.1177/1076217520940747

Vidergor, H. (2020). The case of a leadership course based on the multidimensional curriculum model: gifted elementary students' perceptions. *Roeper Review, 42,* 179–191. https://doi.org/10.1080/02783193.2020.1765922

Vitale, P., & Johnson, B. (1988). A factor analytic study of the attitudes of gifted secondary students toward science. *Educational and Psychological Measurement*, 48, 1011–1018. https://doi.org/10.1177/0013164488484016

Vogl, K., & Preckel, F. (2014). Full–time ability grouping of gifted students. *Gifted Child Quarterly*, *58*, 51 – 68. https://doi.org/10.1177/0016986213513795

Voitova, T., Bernhofs, V., & Müllensiefen, D. (2025). The influence of psychosocial skills on the development of musical abilities: Cross-sectional results from secondary school pupils in Latvia, *Gifted Child Quarterly*, 184–201. https://doi.org/10.1177/00169862241307660

Watters, J., & Diezmann, C. (2003). The gifted student in science: Fulfilling potential. *Australian Science Teachers' Journal, 49*(3), 46–53. https://eprints.qut.edu.au/1692/

Westberg, K., Archambault, F., Dobyns, S. and Slavin, T. (1993). *An observational study of instructional and curricular practices used with gifted and talented students in regular classrooms.* Storrs, CT: National Research Center on the Gifted and Talented.

Winebrenner, S. (2000). Gifted students need an education, Too. *Educational Leadership*, *58*(1), 52–56.

https://doi.org/10.33225/jbse/25.24.296

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Yang, I. H., & Park, S. O. (2015). Analysis of science gifted elementary students' perceptions about laboratory–based science learning. *Journal of the Korean Society of Earth Science Education*, *8*(2), 164–182. https://doi.org/10.15523/JKSESE.2015.8.2.164

Yang, I., Choi, H., & Lim, S. (2014). A comparison between the perceptions of elementary gifted child and science teacher about the good science class. *Journal of the Korean Association for Research in Science Education*, *34*, 10–20. https://doi.org/10.14697/JKASE.2014.34.1.1.00010

Yoon, J., Kim, K. J., & Koo, K. (2020). Enrichment program for the ethnic minority of gifted and talented students in science and engineering. *International Journal of Science Education, Part B*, *10*(1), 36–50. https://doi.org/10.1080/21548455.2020.1714092

Zacharia, Z. (2003). Beliefs, attitudes, and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *40*(8), 792–823. https://doi.org/10.1002/tea.10112

Zhou, D., Gomez, R., Davis, J., & Rittenbruch, M. (2023). Engaging solution–based design process for integrated STEM program development: An exploratory study through autoethnographic design practice. *International Journal of Technology and Design Education*, *33*(2), 717–748. https://doi.org/10.1007/s10798–022–09745–2

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THE IMPACT OF DIGITAL LITERACY AND DISASTER MITIGATION UNDERSTANDING ON COMPUTATIONAL AND SPATIAL THINKING ABILITY IN UPPER SECONDARY SCHOOL STUDENTS

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Abstract. *Computational thinking and spatial thinking ability play a critical role in enabling students to respond effectively to disasters. However, limited research has examined the impact of digital literacy, disaster education, and cognitive skills in secondary school students. This study aims to assess the impact of digital literacy and disaster mitigation understanding on the development of computational and spatial thinking ability in upper secondary school students. A quantitative research approach was employed using Structural Equation Modeling to analyze the impact of the variables. The research participants in this study consisted of 258 students enrolled in two upper secondary schools, namely Public Senior High School 21 Makassar and Public Senior High School 4 Barru. Data were collected through questionnaires and performance-based tests. The results revealed that digital literacy positively impacted computational thinking and spatial thinking. Similarly, disaster mitigation understanding positively impacted computational thinking and spatial thinking. Moreover, computational thinking demonstrated a moderate positive impact on spatial thinking, indicating a strong interaction between these cognitive domains. These findings suggest that students with higher digital literacy and disaster knowledge exhibit stronger problem-solving and spatial reasoning skills, which are crucial for disaster preparedness and risk mitigation.*

Keywords: *digital literacy, disaster mitigation understanding, computational thinking, spatial thinking, upper secondary school*

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Introduction

The integration of digital literacy into education has gained significant attention in recent years due to its potential to enhance students' cognitive skills, particularly computational and spatial thinking. These skills are essential for preparing students to address 21st-century challenges, where technology and data-driven problem-solving play a fundamental role. Computational thinking, which involves problem decomposition, pattern recognition, and algorithmic design, enables students to approach complex problems systematically (Jacob & Warschauer, 2018; Santosa, 2024; Üzümcü & Bay, 2020; Verawati, 2023). In parallel, spatial thinking helps students visualize and interpret spatial relationships between objects, allowing them to better engage with real-world phenomena (Park & Kwon, 2022; Tsai & Wang, 2021). Disaster mitigation, a multifaceted field, requires both spatial understanding and problem-solving abilities, which can be effectively enhanced through these cognitive skills.

Research has emphasized the importance of disaster mitigation education for secondary school students, as they are at a critical developmental stage where such knowledge can impact their behavior and decision-making. Previous studies have found that students equipped with disaster mitigation skills are more likely to engage in risk-reduction behaviors and demonstrate heightened awareness of environmental threats (Atmojo et al., 2018; Ayub et al., 2022; Gadeng et al., 2022; Perbawasari et al., 2020; Rofiah et al., 2021). Comprehensive disaster education curricula implemented in schools have been shown to improve students' preparedness and understanding of potential environmental threats (Gadeng et al., 2022; Rofiah et al., 2021). For instance, integrating disaster literacy into school programs has significantly enhanced students' understanding of disaster risks and their ability to respond

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appropriately (Logayah, 2023). However, despite these advancements, limited empirical research has explored the interaction between digital literacy and disaster mitigation education in fostering computational and spatial thinking ability, particularly in secondary school contexts.

The primary issue addressed in this study is the limited understanding of how digital literacy and disaster mitigation education collectively impact computational and spatial thinking ability among secondary school students. A comprehensive examination of these relationships is necessary to uncover mechanisms by which digital literacy and disaster education support critical cognitive skills, providing insights for improving curriculum design.

Existing research has highlighted the role of digital literacy in enhancing cognitive abilities, particularly computational thinking, which is a key skill for navigating the digital age. Digital literacy encompasses a range of competencies, including the ability to effectively use digital tools, critically evaluate information, and engage in problem-solving processes foundational to computational thinking (Koçak & Göksu, 2020; Nurwahidah et al., 2021; Tian, 2023). Students with strong digital literacy skills are better equipped to analyze problems and design effective solutions using technology (Cintamulya et al., 2023; Gümüş, 2024; Pratiwi et al., 2023). Digital literacy has been found to improve engagement and enable students to approach problems algorithmically, further enhancing their computational thinking ability (Kesici, 2022; Cintamulya et al., 2023; Leuwol, 2023).

Spatial thinking is also crucial in disaster mitigation education, as it enables students to analyze geographic and environmental data necessary for predicting and responding to natural hazards. Spatial reasoning allows students to visualize data related to hazards, vulnerabilities, and available resources, thereby enhancing disaster preparedness and response strategies. Previous studies have indicated that spatial thinking ability enables students to effectively utilize tools like Geographic Information Systems (GIS) and spatial analysis techniques to assess risks and develop mitigation strategies (Wahyu et al., 2023; Purwanto et al., 2023). For instance, students trained in spatial analysis have demonstrated improved abilities to assess flood risks and devise spatial planning policies to mitigate such hazards. Disaster mitigation education inherently involves the interpretation of spatial data, fostering critical thinking and problem-solving abilities essential for reducing disaster impacts.

While previous research has examined digital literacy and disaster mitigation separately, little research has examined their combined impact on computational and spatial thinking ability, especially in secondary education. For example, GIS tools have been found to help students analyze spatial data in disaster education contexts, enhancing their understanding of disaster dynamics (Logayah, 2023). Similarly, digital storytelling projects that integrate disaster scenarios have been shown to encourage critical thinking and problem-solving, fostering both computational and spatial thinking ability (Vice et al., 2024). However, there remains a gap in the literature regarding the comprehensive effects of integrating digital literacy and disaster mitigation education on these cognitive skills.

This study addressed this research gap by assessing the impact of digital literacy and disaster mitigation education on computational and spatial thinking ability in upper secondary school students. The research hypotheses were as follows:

H_1: Disaster mitigation understanding impacts computational thinking ability
H_2: Disaster mitigation understanding impacts spatial thinking ability
H_3: Digital literacy impacts computational thinking ability
H_4: Digital literacy impacts spatial thinking ability
H_5: Computational thinking ability impacts spatial thinking ability

The novelty of this research lies in its interdisciplinary approach, combining digital literacy and disaster education to examine their collective impact on cognitive development. This research is justified by the need for a comprehensive understanding of how these domains can be integrated into secondary education curricula to foster essential cognitive skills. Developing computational and spatial thinking abilities is crucial for problem-solving and decision-making in complex scenarios.

Research Methodology

Design

This study employed a quantitative research approach to assessing the impact of digital literacy, disaster mitigation understanding on computational and spatial thinking in upper secondary school students. A correlational research design incorporating SEM was utilized for data analysis.

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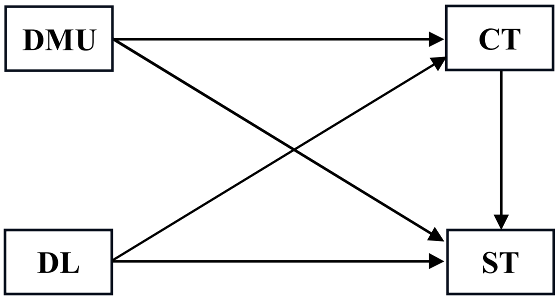
Figure 1
SEM Model Diagram



This design facilitates the examination of direct and indirect impacts between digital literacy, disaster mitigation understanding, and computational and spatial thinking ability. Cross-sectional data were collected through a survey instrument, and SEM was used to evaluate measurement validity and structural pathways among the variables. This design is in line with the research designs of Mariam et al (2021) and Matsuno and Hirano (2021), which demonstrate the efficacy of SEM in educational research, especially in analyzing the interaction between educational factors and student learning outcomes.

Participants

The participants of this study consisted of upper secondary school students from schools that have officially integrated digital literacy and disaster mitigation education into their curriculum. The selection of participants followed a stratified random sampling technique to ensure that the sample was sufficiently representative of students in different grade levels while maintaining diversity in their exposure to digital literacy and disaster mitigation education.

The research participants in this study consisted of 258 students enrolled in upper secondary schools, namely Public Senior High School 21 Makassar and Public Senior High School 4 Barru. Since both schools have formally integrated digital literacy and disaster mitigation education into their curricula, all students already met the foundational criteria for inclusion in this study. The sample size of 258 students was based on students who voluntarily agreed to participate in the study after receiving informed consent. The distribution of participants was based on their grade level, to ensure a representative sampling of grades X, XI, and XII (Table 1). This stratification allows for potential variations in digital literacy, disaster mitigation understanding, and cognitive skill development across different academic levels.

Table 1
Research Sample from 3 Different Grade Levels

Item	Grade	Total	%
Male Students	X	39	15.12
	XI	41	15.89
	XII	34	13.18
Female Students	X	43	16.67
	XI	54	20.92
	XII	47	18.22
Total		258	100

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Research Instruments

The research instruments consisted of a structured questionnaire and performance-based tests designed to measure students' competencies in digital literacy, disaster mitigation understanding, computational thinking, and spatial thinking ability. The development of these instruments was based on an extensive literature review and expert consultation to ensure content validity and reliability.

The structured questionnaire was employed to measure students' digital literacy and understanding of disaster mitigation. This questionnaire consisted of two main sections. The first section focused on digital literacy, meanwhile the second section measured disaster mitigation understanding. The statements of each indicator in the structured questionnaire are summarized in Table 2.

Each section included six items scored on a 4-point Likert scale (1 = strongly disagree to 4 = strongly agree). The questionnaire was pilot-tested with 50 students to evaluate its clarity and reliability. Expert feedback from three senior academics specializing in disaster education and digital literacy was incorporated to refine the instrument. Reliability was established using Cronbach's Alpha, with all constructs exceeding the recommended threshold of .70, confirming internal consistency.

A performance-based test was used to measure students' computational and spatial thinking abilities. The test consisted of 16 open-ended questions, which were divided equally between the computational thinking and spatial thinking assessments. The computational thinking component consisted of eight questions that tested students' ability to decompose problems, recognize patterns and apply algorithmic thinking in disaster scenarios. The spatial thinking component, which also consisted of eight questions, measured students' ability to interpret maps, analyze spatial relationships, and apply geographic information in a disaster context. The indicators of each indicator in the tes instrument are summarized in Table 3.

The test items were adapted from established computational and geographic education research frameworks. To ensure their validity, an expert review and content analysis were conducted, leading to necessary modifications based on expert recommendations. Additionally, Confirmatory Factor Analysis (CFA) was performed to validate the construct reliability of the test items. The outer loading values ranged between .811 and .841, indicating strong factor loadings for each indicator. Furthermore, the Average Variance Extracted (*AVE*) scores exceeded .50, confirming both convergent and discriminant validity of the instrument.

Prior to data collection, ethical approval was obtained from the respective school authorities. All participants were informed about the study's objectives, the confidentiality of their responses, and their voluntary participation. To adhere to ethical research principles, written consent was secured from all participants, ensuring that they understood their rights and the anonymity of their responses.

This methodological approach ensured that the instruments used in this study were both scientifically rigorous and ethically sound, allowing for a reliable assessment of students' digital literacy, disaster mitigation understanding, and cognitive skills related to computational and spatial thinking.

Table 2
The Statement of Each Indicator in The Structured Questionnaire

Indicators	Statements	Reference
DMU1	I understand the importance of disaster mitigation in reducing the impact of natural disasters	(Setiawati et al., 2022; Wahyono et al., 2022)
DMU2	I understand the different types of natural disasters that can occur in my region	(Ahmad et al., 2022; Prasetyo, 2022)
DMU3	I am aware of the different stages of disaster mitigation, including prevention, preparedness, response, and recovery	(Çalışkan & Üner, 2020)
DMU4	I am familiar with my community's disaster response plan	(Setiawati et al., 2022; Subekti et al., 2020)
DMU5	I understand the role of local government and emergency services in disaster mitigation	(Ekawati et al., 2022; Joakim & Doberstein, 2013)
DMU6	I understand the role of technology and innovation in enhancing disaster mitigation efforts, such as the use of GIS, remote sensing, and digital tools	(Ariyachandra & Wedawatta, 2023; Jiang, 2022)

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Indicators	Statements	Reference
DL1	I can effectively search for and evaluate information related to disaster mitigation from online sources	(Asteria, 2023)
DL2	I can critically analyze the credibility and reliability of disaster-related information shared on social media	(Asteria, 2023)
DL3	I can understand and interpret data visualizations (e.g., maps, graphs) related to disaster risks and mitigation strategies	(Logayah, 2023)
DL4	I can use digital technologies (e.g., mobile apps, websites) to stay informed about early warning systems and emergency procedures for disasters	(Prananingrum, 2023)
DL5	I can use online resources to learn about the specific disaster risks and mitigation strategies relevant to my local area	(Nafi'ah, 2023)
DL6	I can use digital tools to simulate and model disaster scenarios to better understand mitigation strategies	(Zamroh et al., 2022)

Table 3
The Indicator of Each Item Variable in The Tes Instrument

Indicators	Competence	Reference
CT1	Students are able to identify natural disaster problems faced by the community and formulate appropriate solutions to reduce the impact of disasters based on available data.	(Jairina et al., 2018)
CT2	Students are able to systematically organize steps or sequences of procedures for disaster mitigation (e.g. evacuation steps or handling after a disaster)	(Supiarmo et al., 2021)
CT3	Students can identify the most relevant information in the disaster mitigation process, such as focusing on important factors (e.g., geographical conditions, weather, and potential hazards)	(Supiarmo et al., 2021)
CT4	Students can detail the stages or steps of mitigation actions based on measurable or learnable components	(Supiarmo et al., 2021)
CT5	Students are able to collect and analyze disaster-related data (e.g., weather, topography, or population data) to support mitigation decisions	(Lawrence et al., 2020)
CT6	Students are able to recognize the relationship between natural disaster phenomena and other contributing factors (e.g., season, topography, or human activities).	(Supiarmo et al., 2021)
ST1	Students are able to read and understand topographic maps or maps of disaster areas.	(Charcharos et al., 2015)
ST2	Students are able to visualize disaster scenarios from map data or images, such as projecting the potential for flooding or the spread of forest fires	(Fischer et al., 2007; Lloyd, 2000)
ST3	Students understand the different scales on maps and can interpret distances or sizes accurately	(Kerski, 2008)
ST4	Students are able to rotate or project the rotation or change of orientation of objects on a map, for example, understanding how a stream of water or wind will move in a given situation	(Bednarz et al., 2007)
ST5	Students are able to identify spatial relationships between different objects in a disaster area, for example, how the distance between a volcano and a settlement affects the risk of eruption	(Astawa et al., 2022)
ST6	Students can explain the relative position between objects on the map, such as rivers, mountains, and settlements.	(Koch & Sheehan, 2014; Fischer & Sholl, 2008)

Data Collection

Data collection techniques were conducted systemically to ensure data validity and reliability. Data were collected using two research instruments consisting of a structured questionnaire and a performance-based test. These instruments were designed to assess students' digital literacy, disaster mitigation understanding, computational thinking, and spatial thinking ability. The structured questionnaire was used to measure students' digital literacy and understanding of disaster mitigation. Meanwhile, performance-based tests were used to measure students' computational and spatial thinking ability.

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Data collection was conducted in a controlled classroom under the supervision of researchers and trained teachers to minimize outside interference. Students were given a specific time allocation to complete the questionnaires and tests. The researchers gave clear instructions and answered any questions raised by the participants before the assessment began.

Data Analysis

Data analysis was conducted using Structural Equation Modeling (SEM) to test the hypothesized model and determine the strength of the impact between variables. This approach was chosen due to its effectiveness in establishing correlations and cause-and-effect relationships within educational research, particularly in disaster preparedness and literacy contexts (Cabuga & Cañete, 2023; Yildiz, 2023). Structural Equation Modeling (SEM) was used to analyze the collected data, testing the measurement models and structural impacts between digital literacy, disaster mitigation understanding, and computational and spatial thinking ability. Analyses began with confirmatory factor analysis (CFA) to verify the validity and reliability of the measurement model. Validity was assessed through outer loading (> .70), and reliability was evaluated through Cronbach's Alpha (> .70), Rho A (> .70), Composite Reliability (> .70), and convergent validity via *AVE* (> .50). Discriminant validity was examined using the Fornell-Larcker criterion, ensuring the square root of *AVE* (diagonal) for each variable exceeded other variable correlations, and by verifying that cross-loading values were highest within their respective constructs (Hair, 2019). Internal consistency values ranged from 0 to 1, with higher values indicating greater reliability. Path analysis was conducted to evaluate the direct and indirect effects of digital literacy and disaster mitigation understanding on computational and spatial thinking ability, as reflected in SEM regression weights. Bootstrap T and F statistical tests were performed using 5000 subsamples to determine the significance of path coefficients ($T > 1.96$, $p < .05$) at a 95% confidence interval (Hair, 2019).

Research Results

The Structural Equation Modeling (SEM) analysis revealed the strength of relationships between indicators and the measured latent variables: Computational Thinking (CT), Digital Literacy (DL), Spatial Thinking (ST), and Disaster Mitigation Understanding (DMU). Table 4 shows that all indicators have high outer loading values (ranging from .81 to .84), indicating strong contributions of each indicator to their respective latent variables. This confirms that the measurement model is valid and suitable for evaluating relationships among the latent variables in this study.

Table 4
Outer Loadings

Indicators	Computational Thinking	Digital Literacy	Spatial Thinking Ability	Understanding Disaster Mitigation
CT1	.83			
CT2	.81			
CT3	.83			
CT4	.83			
CT5	.84			
CT6	.84			
DL1		.82		
DL2		.83		
DL3		.83		
DL4		.82		
DL5		.84		

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Indicators	Computational Thinking	Digital Literacy	Spatial Thinking Ability	Understanding Disaster Mitigation
DL6		.83		
ST1			.83	
ST2			.84	
ST3			.84	
ST4			.84	
ST5			.81	
ST6			.83	
DMU1				.82
DMU2				.83
DMU3				.83
DMU4				.82
DMU5				.83
DMU6				.82

All latent variables—Computational Thinking (CT), Digital Literacy (DL), Spatial Thinking (ST), and Disaster Mitigation Understanding (DMU)—demonstrated excellent reliability, as evidenced by high Cronbach's Alpha (α) and Composite Reliability (*CR*) values. Additionally, the *AVE* values for all latent variables exceeded .5, confirming good validity (see Table 5). Thus, the evaluation of the measurement model for convergent validity was successfully fulfilled (Hair Jr. et al., 2021). The reflective measurement model displayed strong internal consistency, accurately measuring the latent variables.

Table 5
Construct Reliability and Validity

Variables	α	ρ_a	*CR*	*AVE*
Computational Thinking	.910	.910	.930	.690
Digital Literacy	.907	.907	.928	.682
Spatial Thinking	.910	.910	.930	.690
Disaster Mitigation Understanding	.906	.906	.927	.680

Table 6 presents the evaluation of discriminant validity using the Fornell-Larcker Criterion. The values in bold represent the square root of *AVE*, while the other values represent the correlation coefficients between constructs. Each construct's square root of the *AVE* was greater than its correlations with other constructs, indicating robust discriminant validity. The *AVE* square root values for Computational Thinking (.83), Digital Literacy (.83), Spatial Thinking (.83), and Understanding Disaster Mitigation (.82) confirm that each construct is distinct and free of overlapping variables. Thus, the discriminant validity evaluation based on the Fornell-Larcker Criterion is acceptable.

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Table 6
Discriminant Validity (Fornell-Larcker Criterion)

Variables	Computational Thinking	Digital Literacy	Spatial Thinking	Disaster Mitigation Understanding
Computational Thinking	**.83**			
Digital Literacy	.91	**.83**		
Spatial Thinking	.91	.91	**.83**	
Disaster Mitigation Understanding	.91	.92	.91	**.82**

Table 7 provides the cross-loading results between indicators and their corresponding latent variables. The indicators displayed the highest loadings on their intended latent variables compared to other latent variables, indicating that each construct strongly measures its respective domain. This further confirms the adequacy of discriminant validity, with variables more closely related to their main constructs than to others.

Table 7
Indicator Cross-loading

Indicators	Computational Thinking	Digital Literacy	Spatial Thinking	Disaster Mitigation Understanding
CT1	.83	.76	.76	.74
CT2	.81	.76	.74	.74
CT3	.83	.75	.77	.77
CT4	.83	.74	.77	.75
CT5	.84	.77	.74	.76
CT6	.84	.77	.76	.76
DL1	.74	.82	.76	.76
DL2	.75	.83	.73	.75
DL3	.77	.83	.76	.76
DL4	.75	.82	.75	.75
DL5	.74	.84	.75	.77
DL6	.77	.83	.75	.75
ST1	.78	.76	.83	.74
ST2	.76	.78	.84	.78
ST3	.75	.76	.84	.76
ST4	.76	.73	.84	.75
ST5	.74	.76	.82	.75
ST6	.76	.74	.83	.75
DMU1	.75	.77	.74	.85
DMU2	.74	.77	.77	.83
DMU3	.76	.75	.74	.83
DMU4	.73	.77	.76	.82
DMU5	.74	.74	.75	.83
DMU6	.76	.75	.76	.82

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The results of hypothesis testing, path coefficients, and item loadings for the research variables are summarized in Table 8 and illustrated in Figure 2. Hypothesis testing demonstrated significant relationships between all variables, with *p-Values* of .00 for all tested paths, indicating statistically significant effects. The path coefficients reveal the following:

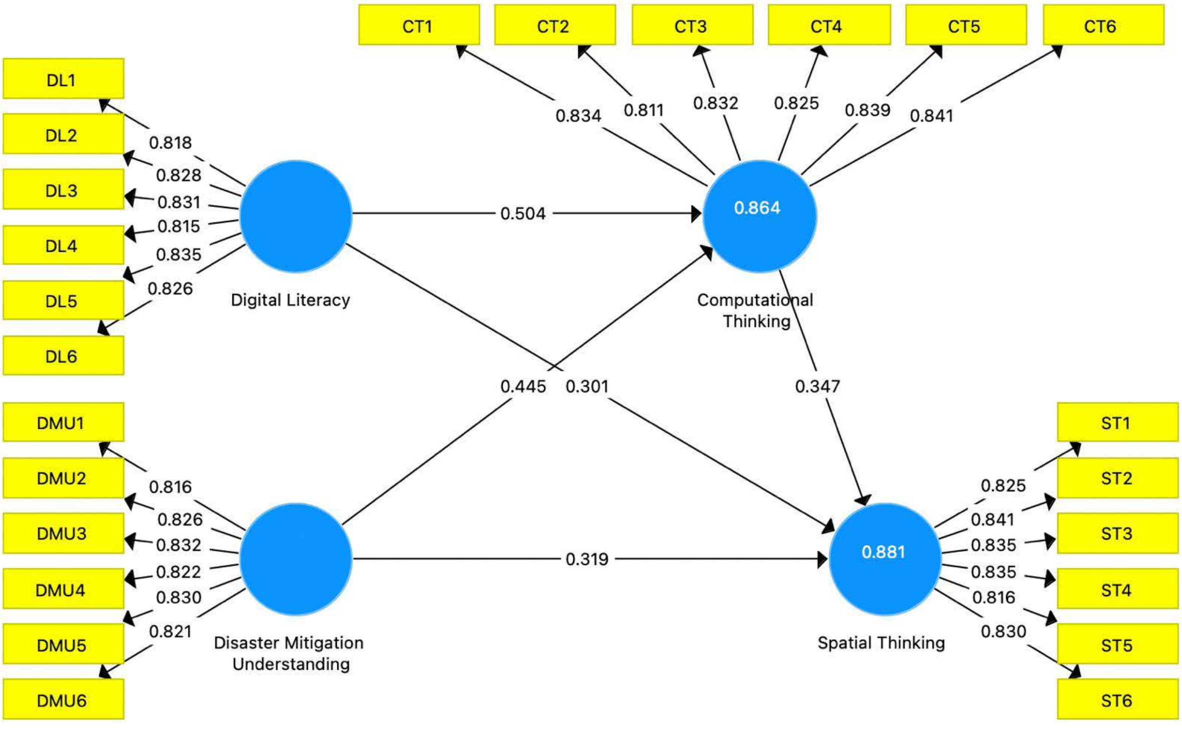
- Computational Thinking positively impacted on Spatial Thinking, with a coefficient of .35.
- Digital Literacy positively impacted on Computational Thinking (coefficient: .50) and Spatial Thinking (coefficient: .48).
- Understanding Disaster Mitigation affects Computational Thinking (coefficient: .45) and Spatial Thinking (coefficient: .47).

Moreover, high item loadings confirm that the variables consistently and strongly measure their respective latent constructs. Collectively, these findings support the hypotheses that digital literacy and disaster mitigation understanding significantly impact computational and spatial thinking ability. These results highlight the critical role of enhancing digital literacy and disaster mitigation understanding in fostering essential cognitive skills.

Table 8
Hypothesis Testing Results (Path Coefficients and Significance Levels)

Path (Hypothesis)	β	*M*	*SE*	T-Statistic (|β/SE|)	*p-Value*	Significance
H_1: DMU → CT	.45	.44	.06	7.63	< .01	Significant
H_2: DMU → ST	.47	.47	.05	8.84	< .01	Significant
H_3: DL → CT	.50	.50	.06	8.57	< .01	Significant
H_4: DL → ST	.48	.48	.05	8.85	< .01	Significant
H_5: CT → ST	.35	.35	.05	6.47	< .01	Significant

Figure 2
SEM Analysis Results



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Discussion

The findings of this study revealed significant interconnections between digital literacy, disaster mitigation understanding, and the development of computational and spatial thinking ability in upper secondary school students. Digital literacy significantly enhanced computational thinking ($\beta = .504$, $p < .001$) and spatial thinking ($\beta = .476$, $p < .001$). Similarly, disaster mitigation understanding had a substantial positive impact on computational thinking ($\beta = .445$, $p < .001$) and spatial thinking ($\beta = .473$, $p < .001$). These findings underscore the transformative potential of integrating digital literacy and disaster education into curricula. Additionally, computational thinking skills significantly contributed to spatial thinking ($\beta = .347$), indicating a synergistic relationship between these cognitive domains.

The findings align with existing literature that highlights the importance of digital literacy and disaster education in enhancing cognitive abilities. For example, Koçak and Göksu (2020) and Nurwahidah et al. (2021) demonstrated that digital literacy promotes computational thinking through algorithmic reasoning and problem-solving. Research by Wahyu et al. (2023) emphasized the role of spatial thinking in disaster preparedness, enabling effective analysis and interpretation of geographic data. However, this study advances the field by quantitatively elucidating the interactions among these variables through structural equation modeling (SEM). Compared to prior research, it offers deeper insights into how digital literacy and disaster education collectively shape spatial and computational cognition, an area previously underexplored.

The study's findings have significant implications for educational practices and curriculum design. By demonstrating that digital literacy and disaster mitigation understanding directly enhance critical cognitive skills, the study underscores the importance of embedding these components into educational strategies. Such integration equips students with the ability to tackle complex, real-world challenges, including disaster response and technological problem-solving. The positive correlation between computational and spatial thinking ability indicates that enhancing one domain can indirectly benefit the other, providing educators with a framework for interdisciplinary approaches. These results are particularly relevant for fostering 21st-century skills, resilience, and informed decision-making in students.

The findings are consistent with theoretical frameworks emphasizing the interconnectedness of cognitive skills, as highlighted in constructivist and systems thinking theories. Constructivist approaches advocate active learning, where digital literacy fosters problem-solving and knowledge construction through technology (Kesici, 2022). Similarly, systems thinking supports spatial cognition by enabling learners to model and interpret complex relationships within disaster scenarios (Hasnawiyah, 2024). The study also builds on research demonstrating the efficacy of Geographic Information Systems (GIS) and simulation-based learning in disaster education, which simultaneously enhance spatial reasoning and preparedness (Logayah, 2023; Wahyu et al., 2023).

While this research effectively addresses its primary objective by examining the impact of digital literacy and disaster mitigation education on computational and spatial thinking ability, some limitations must be acknowledged. First, this study employed a cross-sectional design, which limits the ability to establish causality over time. Future research should consider a longitudinal approach to better understand the long-term effects of digital literacy and disaster education on cognitive skill development. Additionally, socio-cultural factors may influence students' engagement with digital literacy and disaster education, suggesting a need for further research into contextual variables.

Despite these limitations, this study makes a significant contribution by offering empirical evidence on how integrating digital literacy and disaster mitigation education can enhance computational and spatial thinking ability. The findings support the growing body of literature advocating for interdisciplinary approaches to education that prepare students for complex problem-solving in the digital age. Future studies should explore additional instructional strategies, such as game-based learning and virtual reality simulations, to further enhance students' cognitive skills in disaster preparedness and digital literacy.

Conclusions and Implications

This study has provided empirical evidence that the integration of digital literacy and disaster mitigation education significantly enhances students' computational and spatial thinking ability. The findings indicate that digital literacy positively impacted computational thinking and spatial thinking. Similarly, disaster mitigation understanding contributes to the improvement of computational thinking and spatial thinking. Furthermore,

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computational thinking demonstrates a direct impact on spatial thinking, suggesting an intrinsic relationship between these cognitive abilities.

These findings underscore the importance of integrating digital literacy and disaster mitigation education into formal curricula as a means of fostering students' cognitive competencies in a technology-driven world. The empirical evidence supports the necessity of interdisciplinary learning models that incorporate both digital and disaster-related knowledge, equipping students with essential problem-solving and analytical skills required for contemporary global challenges.

From an educational perspective, the results highlight the need for curriculum innovation that integrates digital technologies and disaster preparedness into secondary education. The incorporation of digital tools, such as Geographic Information Systems (GIS) and simulation-based learning platforms, can enhance students' analytical abilities and disaster response competencies. Additionally, teacher professional development programs should emphasize pedagogical strategies that utilize digital literacy as a vehicle for enhancing disaster education.

From a policy standpoint, educational institutions and policymakers should prioritize the integration of interdisciplinary approaches in curriculum development, particularly in regions vulnerable to natural disasters. The adoption of digital literacy and disaster education can serve as a proactive measure in cultivating a generation of students equipped with the necessary cognitive and practical skills to navigate disaster-prone environments effectively.

For future research, longitudinal studies are recommended to examine the sustained impact of digital literacy and disaster mitigation education on students' cognitive skill development. Additionally, further research should explore the impact of socio-cultural factors on students' engagement with digital and disaster-related learning. Experimental studies may also be conducted to compare the effectiveness of various instructional methods, such as gamified learning, augmented reality, and collaborative problem-solving approaches, in fostering computational and spatial thinking ability.

This study provides empirical evidence supporting the integration of digital literacy and disaster mitigation education as a means of strengthening students' cognitive abilities. By fostering computational and spatial thinking, such interdisciplinary approaches can better prepare students to navigate complex, technology-driven challenges and contribute to disaster-resilient communities. Future research should continue exploring innovative educational strategies to enhance student preparedness, resilience, and analytical skills in addressing global challenges.

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Declaration of Interest

The authors declare no competing interest.

References

Ahmad, D., Shah, S. Z. A., & Ayub, M. (2022). Determining economic losses and factors influencing flood, drought and earthquake risk perception in disaster-prone areas of Punjab, Pakistan. *Pakistan Journal of Humanities and Social Sciences, 10*(3), 1068–1081. https://doi.org/10.52131/pjhss.2022.1003.0269

Ariyachandra, M. F., & Wedawatta, G. (2023). Digital twin smart cities for disaster risk management: A review of evolving concepts. *Sustainability, 15*(15), Article 1191. https://doi.org/10.3390/su151511910

Astawa, I. B. M., Citrawathi, D. M., Sudiana, I. K., & Wulandari, I. G. A. A. M. (2022). The effect of flipped classroom based on disaster map visualization in disaster mitigation learning on students' self-efficacy and critical thinking skills. *Jurnal Pendidikan IPA Indonesia, 11*(2), 303–313. https://doi.org/10.15294/jpii.v11i2.35308

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Asteria, D. (2023). Integration of local capacity building in countering false information about disaster into community-based disaster risk management. *IOP Conference Series: Earth and Environmental Science, 1275*(1), Article 012028. https://doi.org/10.1088/1755-1315/1275/1/012028

Atmojo, S. E., Rusilowati, A., Dwiningrum, S. I. A., & Skotnicka, M. (2018). The reconstruction of disaster knowledge through thematic learning of science, environment, technology, and society integrated with local wisdom. *Jurnal Pendidikan IPA Indonesia, 7*(2), 204–213. https://doi.org/10.15294/jpii.v7i2.14273

Ayub, S., Kosim, K., Gunada, I. W., & Syahidi, K. (2022). Effectiveness of student oriented disaster mitigation learning model on students' disaster awareness in primary school. *Kappa Journal*, *6*(1), 71–91. https://doi.org/10.29408/kpj.v6i1.5750

Bednarz, S. W., & O'Loughlin, M. (2007). The development of spatial thinking and geographic information systems in education. *International Journal of Science Education*, *29*(12), 1435–1453. https://doi.org/10.1080/09500690601032488

Cabuga, C. C., & Cañete, R. (2023). Assessment of disaster preparedness and related knowledge among senior high students in Del Pilar National High School, Cabadbaran City, Agusan Del Norte, Philippines. *International Journal of Social Science and Human Research, 6*(6). https://doi.org/10.47191/ijsshr/v6-i6-56

Çalışkan, C., & Üner, S. (2020). Disaster literacy and public health: A systematic review and integration of definitions and models. *Disaster Medicine and Public Health Preparedness, 15*(4), 518–527. https://doi.org/10.1017/dmp.2020.100

Charcharos, C., Tomai, E., & Kokla, M. (2015). Assessing spatial thinking ability. In A. A. Editor & B. B. Editor (Eds.), *Proceedings of the GEOTHNK International Closing Conference, November 7, 2015* (pp. 1–10). Athens, Greece. https://doi.org/10.13140/RG.2.1.1621.0962

Cintamulya, I., Mawartiningsih, L., & Warli, W. (2023). The effect of optimizing digital and information literacy in writing scientific articles on students' critical thinking skills. *Al-Ishlah: Jurnal Pendidikan, 15*(2), 1987–1998. http://doi.org/10.35445/alishlah.v15i2.3062

Council, N. R. (2006). *National Sciene Education Standards.* National Academy Press.

Ekawati, J., Sulistyowati, E., Hardiman, G., & Pandelaki, E. E. (2022). Community response to disaster mitigation in the impacted area of mudflow disaster. *Journal of Urban and Regional Analysis*, *14*(2). https://doi.org/10.37043/jura.2022.14.2.7

Fischer, M. H., & Sholl, M. (2008). The development of spatial thinking in childhood and adolescence: A review of theories and applications. *Cognitive Development, 23*(2), 85–105. https://doi.org/10.1016/j.cogdev.2007.12.004

Gadeng, A. N., Maryani, E., Ningrum, E., & Setiawan, I. (2022). The implementation of disaster curriculum toward disaster preparedness campus at Syiah Kuala University. *Geosfera Indonesia, 7*(3), Article 304. https://doi.org/10.19184/geosi.v7i3.30246

Gümüş, M. M., Kukul, V., & Korkmaz, Ö. (2024). Relationships between middle school students' digital literacy skills, computer programming self-efficacy, and computational thinking self-efficacy. *Informatics in Education, 23*(3), 571–592. https://doi.org/10.15388/infedu.2024.20

Hair, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021). *Partial least squares structural equation modeling (PLS-SEM) using R*. Springer. https://doi.org/10.1007/978-3-030-80519-7

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review, 31*(1), 2–24. https://doi.org/10.1108/EBR-11-2018-0203

Hasnawiyah, H. (2024). Dampak penggunaan media pembelajaran interaktif terhadap prestasi belajar sains siswa [The impact of using interactive learning media on students' science learning achievement]. *Jurnal Review Pendidikan Dasar: Jurnal Kajian Pendidikan dan Hasil Penelitian, 10*(2), 167–172. https://doi.org/10.26740/jrpd.v10n2.p167-172

Jacob, S., & Warschauer, M. (2018). Computational thinking and literacy. *Journal of Computer Science Integration, 1*(1), 1–19. https://doi.org/10.26716/jcsi.2018.01.1.1

Jairina, S. N. I., Handoyo, B., & Astina, I. K. (2018). Pengaruh model pembelajaran problem based learning terhadap kemampuan pemecahan masalah mitigasi bencana [The effect of problem-based learning model on disaster mitigation problem solving skills]. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan, 3*(5), 589–595. http://journal.um.ac.id/index.php/jptpp/article/view/13182

Jiang, Y., Zhang, Z., & Li, X. (2020). Real-time seismic data processing for early warning systems based on GPS and accelerometer sensors. *Seismological Research Letters, 91*(5), 2450–2462. https://doi.org/10.1785/0220200129

Joakim, E., & Doberstein, B. (2013). Policy recommendations for reducing vulnerability to disasters in Canada: Perspectives from practitioners in Waterloo Region, Ontario. *Risk Hazards & Crisis in Public Policy, 4*(4), 274–291. https://doi.org/10.1002/rhc3.12041

Kerski, J. J. (2008). The role of GIS in the development of spatial thinking. *Journal of Geography*, *107*(2), 59–63. https://doi.org/10.1080/00221340802017723

Kesici, A. (2022). The effect of digital literacy on creative thinking disposition: The mediating role of lifelong learning disposition. *Journal of Learning and Teaching in Digital Age, 7*(2), 260–273. https://doi.org/10.53850/joltida.1063509

Koçak, Ö., & Göksu, İ. (2020). Examining 21st-century skill levels of students and the relationship between skills. *İnönü Üniversitesi Eğitim Fakültesi Dergisi, 21*(2), 772–784. https://doi.org/10.17679/inuefd.656784

Koch, D. A., & Sheehan, R. M. (2014). Teaching geography with maps: A comprehensive guide for educators. Teaching Geography, 39(4), 167–177. https://doi.org/10.1080/00940871.2014.922901

Lawrence, M. J., & Turner, S. L. (2020). Data analytics for disaster risk reduction. *Journal of Environmental Science and Risk Management, 27*(1), 45–59. https://journals.sagepub.com/home/esr

Leuwol, F. S. (2023). The role of digital literacy and self-efficacy in enhancing students' critical thinking in learning in the digital era. *Edumaspul: Jurnal Pendidikan, 7*(2), 2678–2685. https://doi.org/10.33487/edumaspul.v7i2.6709

Logayah, D. S. (2023). Understanding disaster literacy level in Indonesia: How can students understand natural disasters? *Al-Ishlah Jurnal Pendidikan, 15*(4), 4962–4971. https://doi.org/10.35445/alishlah.v15i4.3648

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Mariam, I., Budhiana, J., Permana, I., Dewi, R., Rahmanishati, W., Noviyanti, L., Utami, R. N., Sanjaya, W., Ede, A. R. L., & Unmehopa, Y. F. (2021). Knowledge, attitudes, disaster training, and self-efficacy on disaster preparedness. *Research Horizon, 1*(5), 179–188. https://doi.org/10.54518/rh.1.5.2021.179-188

Matsuo, Y., & Hirano, M. (2021). Effectiveness of disaster preparedness education in helping older people prevent isolation. *Public Health Nursing, 38*(5), 837–849. https://doi.org/10.1111/phn.12911

Nafi'ah, K. (2023). Household digital literacy in dealing with landslide disaster. *International Journal of Research and Review, 10*(11), 237–243. https://doi.org/10.52403/ijrr.20231128

Nurwahidah, I., Widiyawati, Y., Sari, D. S., Masykuri, M., & Budiyanto, C. W. (2021). Development of science test to measure HOTS and digital literacy of junior high school students on the topic of city noise. *Edusains, 12*(2), 203–213. https://doi.org/10.15408/es.v12i2.17609

Park, W., & Kwon, H. (2022). Research trends and issues including computational thinking in science education and mathematics education in the Republic of Korea. *Journal of Baltic Science Education, 21*(5), 875–887. https://doi.org/10.33225/jbse/22.21.875

Perbawasari, S., Budiana, H. R., Hafiar, H., Sjoraida, D. F., & Suryawati, I. (2020). Audiobook: Alternative communication media in disseminating disaster mitigation information for children with visual impairments. In A. A. Editor & B. B. Editor (Eds.), *Proceedings of the 3rd International Conference on Advance & Scientific Innovation (ICASI 2020)* (pp. 699–704). EAI. https://doi.org/10.4108/eai.20-6-2020.2300611

Prananingrum, E. N. (2023). Preparedness of school citizens of state elementary school in facing flood through digital literacy. *Mimbar PGSD Undiksha, 11*(1), 140–147. https://doi.org/10.23887/jjpgsd.v11i1.51825

Prasetyo, K. (2022). Flash flood disaster mitigation through environmental education. *Geomatics and Environmental Engineering, 16*(4), 119–134. https://doi.org/10.7494/geom.2022.16.4.119

Prastika, E., Purwanto, A., & Nirwana, N. (2020). Pengaruh pendekatan interactive conceptual instruction (ICI) berbantuan simulasi PhET terhadap hasil belajar siswa [The effect of interactive conceptual instruction (ICI) approach assisted by PhET simulation on student learning outcomes]. *Jurnal Kumparan Fisika, 3*(2), 141–150. https://doi.org/10.33369/jkf.3.2.141-150

Pratiwi, F. A. I., Herlina, K., Viyanti, V., & Andra, D. (2023). Validation of ExPRession learning model-based e-worksheet assisted with Heyzine to construct computational thinking skills. *Jurnal Ilmiah Pendidikan Fisika, 7*(1), 120–130. https://doi.org/10.20527/jipf.v7i1.6329

Purwanto, P., Hidayah, N., & Wagistina, S. (2023). The effect of Gersmehl's spatial learning on students' disaster spatial literacy. *International Journal of Educational Methodology, 9*(2), 345–354. https://doi.org/10.12973/ijem.9.2.345

Rofiah, N. H., Kawai, N., & Hayati, E. N. (2021). Key elements of disaster mitigation education in inclusive school setting in the Indonesian context. *Jàmbá: Journal of Disaster Risk Studies, 13*(1), Article a1159. https://doi.org/10.4102/jamba.v13i1.1159

Santosa, E. B. (2024). Level of computational thinking and technological literacy skills to improve pre-service teacher learning innovation. *Jurnal Kependidikan: Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran, 10*(1), 338–350. https://doi.org/10.33394/jk.v10i1.10872

Setiawati, E., Rizal, M. S., & Budiarti, N. (2022). Dewi Kilisuci figure: Disaster mitigation in the ecofeminism perspective. *Humaniora, 13*(3), 197–203. https://doi.org/10.21512/humaniora.v13i3.7902

Subekti, P., Hafiar, H., & Bakti, I. (2020). Increasing public understanding of disaster by way of educational tourism in Pangandaran, Indonesia. In A. A. Editor & B. B. Editor (Eds.), *Proceedings of the 3rd International Conference on Advance & Scientific Innovation (ICASI 2020)* (pp. 705–710). https://doi.org/10.4108/eai.20-6-2020.2300658

Supiarmo, M. G., Turmudi, & Susanti, E. (2021). Proses berpikir komputasional siswa dalam menyelesaikan soal PISA konten change and relationship berdasarkan self-regulated learning. [Students' computational thinking process in solving PISA questions on change and relationship content based on self-regulated learning]. *Jurnal Numeracy*, *8*(1), 58–72. https://doi.org/10.46244/numeracy.v8i1.1378

Tian, X. (2023). Deep learning influences on higher education students' digital literacy: The mediating role of higher-order thinking. *International Journal of Engineering Pedagogy, 13*(6), 33–49. https://doi.org/10.3991/ijep.v13i6.38177

Tsai, M. J., & Wang, C. Y. (2021). Assessing young students' design thinking disposition and its relationship with computer programming self-efficacy. *Journal of Educational Computing Research, 59*(3), 410–428. https://doi.org/10.1177/0735633120967326

Üzümcü, Ö., & Bay, E. (2021). The effect of computational thinking skill program design developed according to interest-driven creator theory on prospective teachers. *Education and Information Technologies, 26*(1), 565–583. https://doi.org/10.1007/s10639-020-10268-3

Verawati, N. N. S. P. (2023). Examining STEM students' computational thinking skills through interactive practicum utilizing technology. *International Journal of Essential Competencies in Education, 2*(1), 54–65. https://doi.org/10.36312/ijece.v2i1.1360

Vice, T. A., Pittman, R. T., & Warnick, E. M. (2024). Blocked or unlocked: Recognizing the benefits and challenges of digital literacy storytelling projects. *Journal of Education, 204*(2), 468–482. https://doi.org/10.1177/00220574231162590

Wahyono, U., Kade, A., & Untara, K. A. A. (2022). The implementation of local context modules as an effort for disaster risk reduction: An empirical study in disaster-affected schools. *Jurnal Pendidikan IPA Indonesia, 11*(3), 363–373. https://doi.org/10.15294/jpii.v11i3.37399

Wahyu, S., Putri, S., Rahayu, S., Buchori, I., Rahayu, K., Andika, W., Muzaki, A., & Basuki, Y. (2023). Flood hazard risk assessment based on multi-criteria spatial analysis GIS as input for spatial planning policies in Tegal Regency, Indonesia. *Geographica Pannonica, 27*(1), 50–68. https://doi.org/10.5937/gp27-40927

Yildiz, A. (2023). Effects of disaster education on children's risk perception and preparedness: A quasi-experimental longitudinal study. *Geographical Journal*, *190*(2). https://doi.org/10.1111/geoj.12556

Zamroh, M. R. A., Suharini, E., & Aji, A. (2022). Developing GeoHepi application as interactive learning media for flood disaster mitigation materials. *International Journal of Research and Review*, *9*(8), 148–155. https://www.ijrrjournal.com/IJRR_Vol.9_Issue.8_Aug2022/IJRR-Abstract12.html

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SCIENCE IDENTITY AND SCIENCE CAPITAL: EMPIRICAL MAPPING FROM THE PARTICIPATION IN SCIENCE AT SECONDARY SCHOOLS

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Abstract. *Science identity and science capital (SIC) are theoretical lenses to investigate and explain participation in science. However, their qualitative and sociological orientation may limit their effectiveness in promoting science participation from school science education, so some researchers suggested the importance of mapping SIC. This study empirically develops an educational SIC map after a large sample of Spanish students self-reported their science-related attitudes and experiences on a survey. Three different self-recognitions of science participation serve as the basis for statistically identifying the relevant attitudes and experiences that shape the map. The results reveal a map's core set of relevant traits that are prevalent and common across all three self-recognitions, primarily derived from science classes and interest in science topics. Additionally, there is another minoritarian subset, specific to and consistent with each self-recognition, largely associated with science images, technological topics, and digital technologies. The map's relevant traits are further linked to the theoretical dimensions of SIC. The discussion highlights the implications of the map for supporting participation in science from school science education and for advancing research in the field. Some limitations arising from the applied survey and future research directions toward SIC assessment and SIC-oriented science education are also addressed.*

Keywords: *science capital, science identity, science-related attitudes, science participation.*

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Introduction

Societies are increasingly grounded in scientific knowledge, which not only solves but also introduces new and important personal, work-related, and social challenges, such as global warming and pandemics. Various organizations (European Commission, 2004, 2012; OECD, 2016b, 2019; United Nations, 2015) have highlighted that education, particularly science and technology (S&T) education, can help to address these challenges. The concept of scientific and technological literacy for all in S&T supports individuals to achieve the personal, labour, cultural, social, participation, coexistence, and citizenship objectives, as well as fostering democratic and economic social development (National Academies of Sciences, Engineering, and Medicine, 2016).

The increasing development of S&T systems places big demands for skilled personnel that remain unmet in many S&T disciplines. Thus, the challenge of stimulating young people's aspirations to participate in S&T is now an international concern, frequently addressed in specialized research due to its impact on the sustainability of these systems. Although developing scientific vocations has always been a core goal in science education, new educational approaches are currently required to simultaneously satisfy the growing demand for personnel and the principles of educational inclusion and social justice, which are inherent in scientific literacy for all (Archer et al., 2013).

Research Problem

Some studies have introduced the constructs science identity and science capital (hereinafter SIC) as interconnected frameworks that serve as holistic lenses to explain S&T participation. These studies have also proposed some components (competence, action, recognition, literacy, media, etc.) that make sense of data on students' choice of S&T (Archer et al., 2015; Carlone & Johnson, 2007). However, SIC research may remain abstract, generic, qualitative, and not specific enough to facilitate teachers' understanding or support school interventions. For instance, this is particularly critical when the nature of science intersects with SIC (Avraamidou & Schwartz, 2021).

This study addresses this educational gap by empirically incorporating into the abstract and qualitative SIC some specific attitudes and experiences related to S&T education on the basis of the Spanish students' recognition to

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choose S&T studies and its relationship to their self-reported educational attitudes and experiences. This approach is relevant because the specific attitudes and experiences provide educational meaning to SIC components, which can facilitate the design of consistent and appropriate educational interventions on curriculum and methodology development to enhance S&T participation (Kim & Sinatra, 2018; Kim et al., 2018; Vázquez & Manassero, 2009a, 2009b).

Research Focus

The Trends in International Mathematics and Science Study (TIMSS) (Mullis et al., 2021) and the Programme for International Student Assessment (PISA) (OECD, 2019) were designed to assess students' S&T literacy with a focus on cognitive learning, though both included some affective factors in the last waves. These studies have revealed a worrying paradox: students with high TIMSS and PISA scores perceive science education as irrelevant and show little interest toward S&T studies in many countries (OECD, 2016a, 2016b). In the long term, these affective obstacles may harm the personal and social benefits linked to S&T. Thus, fostering positive attitudes toward S&T should be seen as a key objective in school education because it improves learning and other personal and social goods (Dierks et al., 2014; Fensham, 2009). The latest waves of TIMSS (Mullis et al., 2021) and PISA (OECD, 2019) report a slight increase in students' enjoyment of science. However, Spanish PISA 2015 data indicate that 15.3% of students expect to get an S&T job by the age of 30 (López Rupérez et al., 2019).

The international decline of young people's interest in S&T careers (Lyons & Quinn, 2010) is also evident among Spanish youth, as several studies have shown. Zamora (2004) reported a sustained decline of students pursuing high school S&T studies. The Spanish National Institute of Statistics found that enrolments in physical, mathematical, and chemical sciences dropped by 63% between 1999 and 2009 (Rodríguez, 2011). Furthermore, Hernández (2010) reported that first-year enrolments in experimental, technical, and health-related studies decreased by an average of 14% (from 2000 to 2008), despite health studies increasing by 20% and experimental sciences and technical careers sharply declining by 26% and 20%, respectively.

The proportion of 15-18-year-old students in Catalonia choosing S&T studies (33%) varied significantly according to gender and sociocultural status. For example, 51% of high-status boys chose S&T studies, compared to 38% of high-status girls and only 20% of low-status girls (Everis, 2012). Similarly, young people in Spain (15-24 years old) found the scientific profession less attractive (45%) than the older participants (50%), despite valuing higher the personal compensation more and being less concerned about low salaries and job instability compared to older individuals (Fundación Española para la Ciencia y la Tecnología, 2023). Though a bit paradoxical, these overall results do not appear to reflect a general lack of interest in scientific professions among young people.

The current official Spanish statistics on pre-college education provide some up-to-date conclusions. In the 2022 post-compulsory education cohort (+16 years), 45% of students chose S&T studies across high school and vocational training, with a 9% gender gap favouring boys.

Science Identity and Science Capital (SIC)

In recent years, science identity and science capital (SIC) have emerged as complementary frameworks to understand participation in science and technology. These constructs provide a holistic lens to understand why individuals (16 and older) pursue science studies, why certain groups (women, minorities, etc.) remain underrepresented, and why many young people perceive scientific careers as "not for me" (Jenkins & Nelson, 2010). When attempting to understand participation in science, students' aspirations to become scientists appear closely linked to their attitudes toward science, such as interest, enjoyment, and ability (Palmer et al., 2017), as well as to other personal factors (e.g., image, future expectations, etc.) and social variables (e.g., ethnicity, gender, and class). A large majority (75%) of 11-year-old British students reported enjoying school science activities, but only about 17% expressed a desire to pursue scientific careers (DeWitt & Archer, 2015). On the other hand, several studies (Cleaves, 2005; DeWitt et al., 2014; Osborne & Dillon, 2008; Vazquez & Manassero, 2008) have shown a gradual and steady decline in attitudes towards science as students advance through the educational system, resulting in lower attitudes when making decisions to participate or not in S&T.

Science identity facilitates analysing shifts in perspective when scientific aspirations and vocations are due to the different levels of structures (micro, meso, and macro) involved in identity development (Carlone & Johnson, 2007). These researchers defined a person's science identity as the recognition of being a person of science, both self-recognition and recognition by others. They proposed three components to science identity: competence (knowledge of scientific content and processes), action (the ability to use scientific tools and language in daily

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life), and recognition (validation of one's identity by oneself and by others). Science identity is not innate but a developing quality that requires a comprehensive analysis and practices to address the multiple, often conflicting structures, factors, and practices that shape identity.

Butterfield and Marshall's (2022) meta-analysis of 18 studies revealed that many studies did not define science identity but instead used various sociocultural concepts of identity (affinity-identity, discursive identity, culturally situated identity, and social identity). They concluded that science identity is a type of social identity; that is, an awareness of social affiliation with science and the meanings associated with that affiliation. Social psychology further defines social identity as that part of the self-concept derived from group membership. This distinguishes it from personal identity, acknowledges the multiplicity of social identities, and highlights their continuous interaction and evolution within the same individual, altering their relative importance in the self-concept (Kim & Sinatra, 2018; Manstead et al., 1995).

Barriers to the development of science identity include stereotypes, systemic issues, microaggressions, and rejection of the social group. Supports include persistence, competence, action, recognition, and role models (Butterfield & Marshall, 2022). To study the trajectories of identity development, they proposed a three-stage framework (beginner, intermediate, and full member), each characterized by constructs such as competence, action, recognition, intergroup inclusion/rejection, and conflicting social identities. Similarly, Taconis (2022) suggested three basic identities (self, professional role, and social membership), highlighting that the identity construction becomes challenging when other identities come into conflict or dissonance. This researcher proposed mapping identities through pragmatic analysis based on the integration of expertise as a central component of S&T identity.

Science capital builds on Bordieu's concepts of habit and capital, integrating several dimensions and subdimensions. These include scientific forms of cultural capital (scientific literacy, science-related attitudes and dispositions, and transferability to daily life of scientific knowledge), science-related behaviours and practices (scientific media consumption and visits to non-formal science learning environments, centres or museums), and science-related social capital (knowing science workers, parental science qualifications, talking about science, and science identity). Science capital changes depending on the context, and educators can help develop students' science capital by valuing and linking their experiences with science and its different dimensions (Archer et al., 2015). As a result, surveys of science capital are expected to explore, compare, and map its development. They also aim to inform about policy and practice, as well as help practitioners and researchers understand its influence on youth's participation in science.

Research Aim and Research Questions

This study incorporates previous proposals to map SIC and undertakes the search for its specific elements. Social psychology serves as the basic theoretical framework (Manstead et al., 1995): science identity is a special case of social identity and follows the patterns of development and interaction outlined in this framework (Butterfield & Marshall, 2022; Kim & Sinatra, 2018; Taconis, 2022). The science capital dimensions (Archer et al., 2015) and science identity components (Carlone & Johnson, 2007) are treated as hypothetical structures. This study seeks to map and validate by empirically identifying their specific elements.

The SIC map is developed within the framework of the Relevance of Science Education Second (RoseS) research project. RoseS is an exploratory study of students' experiences with school science education based on a self-report questionnaire (RoseS-Q) and the procedures described below. The RoseS project began in 2020 and spanned multiple countries. An international group of experts developed the RoseS-Q and its framework independently of the SIC theoretical frameworks (Jidesjö et al., 2020).

Beyond the mapping aim, RoseS provides data on science participation that enable connections between participation and science education. The rationale for mapping the SIC components from RoseS data is as follows: The ultimate and shared goal of science identity and science capital is to explain S&T participation. Thus, the RoseS variables reveal significant differences between acceptance and rejection of S&T participation that have been helpful to find the elements of the SIC map. Then, the examination of the map's elements may allow assigning them to the SIC component that aligns their content, thereby creating a set of science education variables that constitute a valid and concrete map of each SIC component.

To guide this study, the following research questions are presented:

- RQ1: What are the rates associated with students' S&T affiliation self-recognition?
- RQ2: What educational variables show relevant differences between the acceptance/rejection groups of S&T affiliation self-recognition?

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RQ3: How do these relevant variables map onto and align with the theoretical dimensions/components of SIC?

Research Methodology

General Background

The methodology develops the intersection between SIC research and the RoseS project. The latter has contributed with the data-gathering survey, which has been applied to a large and convenience sample of Spanish secondary students. The quantitative and the qualitative analysis of the large number of variables on students' participation in science, science-related attitudes, and experiences in science education have led to finding the concrete and educational elements of the SIC map.

Participants

The RoseS target population consists of students at the end of their compulsory education (grades 9 and 10, age 15), as they reflect on their education, on what and how they have learned about S&T, and on the important decisions regarding further studies. The original database (2275 records), after quality control and refinement, resulted in a valid sample of 1909 students (49.4% identified as girls, 46.9% as boys, 4.3% did not state their gender, and 213 records were missing). Nearly all the students (97.2%) were between 14 and 16 years old (average age 15.1 years), attended 23 Spanish schools (14 public and 9 private) and none of the participants (institutions, teachers, and students) received any incentives for participating in this study. The responses were collected between 2020 and 2023.

The approval of the RoseS project by the Spanish Research State Agency required a commitment to adhere to ethical principles and comply with relevant national, EU, and international legislation on human Rights. Further, the RoseS-Q presentation informed respondents about the response anonymity, the freedom to leave items blank, the voluntary participation, and that answering implied informed consent. The separation between questionnaire administrators (school teachers) and researchers (who had no contact with respondents) further ensured anonymity. The custody of data by the university (institutional data protector) fully guarantees the respondents' fundamental rights.

Instrument and Procedures

Jidesjö et al. (2020) justified the development of the RoseS-Q based on the statistical and validation analysis of a previous version (Sjøberg & Schreiner, 2019) and a piloting of the new version in four countries. RoseS-Q is made of 167 Likert-type items considered key for the relevance of science education and grouped by thematic affinity into seven categories (Table 1). The items are written as direct, clear, simple, and short phrases (eight words on average), mostly with an affirmative and positive style. However, some items are negatively worded to counteract the acquiescence bias (Table 3 displays some items). The response format is a 4-point Likert scale (1-2-3-4), where most categories ask for disagreement/agreement, while some focus on interest or importance.

Table 1
Description of the RoseS-Q Questionnaire and Details of its Seven Categories

Categories	Label	Number of items	Item Content	Question	Measurement scale (1–4)	Latent Factors	Ordinal Alpha
What I want to learn about	A, C, E	78	S&T Topics	How interested are you in learning about...?	Not interested 1-Very interested 4	-	-
My future job	B	23	Work Traits	How important are the following traits...?	Not important 1 - Very important 4	2	.837 .804
Me and the environmental challenges	D	13	Environmental attitudes	To what extent do you agree with...?	Disagreement 1 – Agreement 4	1	.776

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Categories	Label	Number of items	Item Content	Question	Measurement scale (1–4)	Latent Factors	Ordinal Alpha
My science classes	F	10	Features of school science	To what extent do you agree with…?	Disagreement 1 – Agreement 4	1	.903
My opinions about science and technology (S&T)	G	13	Social aspects of S&T	To what extent do you agree with…?	Disagreement 1 – Agreement 4	2	.857 .811
My experiences of social and digital media	H	16	Social and digital tools for learning	How much do I use…? To what extent do you agree with…?	Usage Time Disagreement 1 – Agreement 4	1	.845
My informal science experiences	I	14	Impact on learning	To what extent do you agree with…?	Disagreement 1 – Agreement 4	2	.876 .859

Note. Ordinal Alpha for latent factor was obtained from confirmatory factor analysis of six scales (B, D, F, G, H, I). A, C, and E scales display quite diverse S&T topics, and factor analysis has been omitted.

Three RoseS-Q items assess different forms of self-recognition in S&T affiliation (hereinafter STAS-R), which serve as the independent variables of this study: becoming a scientist, getting a job in technology, and choosing an S&T subject next year. The latter item (choice of an S&T subject) includes three nominal options (science, another subject, and it depends), which align with the three categories (unequivocal, unthinkable, and insecure) described by DeWitt, Osborne et al. (2013). The responses to the first two items (become a scientist, get a job in technology) assess agreement levels on a 4-point Likert format (Disagreement 1–4 Agreement). The remaining 167 RoseS-Q items constitute the dependent variables (Tables 2 and 3 below).

The online RoseS-Q presented the items alphabetically ordered by their category labels (Table 1) and was administered by teachers to their student groups as a class assignment, following the same protocol across all participating schools. Respondents were informed their participation was anonymous and voluntary and that they could leave items unanswered (thus, some items may have different numbers of valid responses).

Data Analysis

The database was carefully refined to remove invalid answers according to various criteria (null data, homogeneous or inconsistent responses, etc.), ensuring data quality and reducing the likelihood of introducing 'noise' into the analyses. Confirmatory factor analysis identified a nine-factor latent structure for the six scales (B, D, F, G, H, I) of RoseS-Q, with high internal consistency (ordinal Omega index .882) and good factor reliability (Table 1).

A mixed quantitative and qualitative approach was employed to analyse the students' responses. Quantitative parameters were developed and qualitatively interpreted to identify the relevance of variables concerning the study's research questions. The proportion of responses at each Likert scale point quantified response percentages and allowed for the computation of item weighted averages. The distribution of variables did not meet the assumptions of normality and homogeneity of variances. Therefore, non-parametric tests (Mann-Whitney test and Cohen's r and biserial correlation of ranges) were used to calculate significance probabilities and the effect-size (ES) statistics for group differences. Comparisons between the acceptance and rejection groups derived from the three STAS-R independent variables, were performed for the 167 dependent variables (RoseS-Q items). The relevant items for the SIC map were identified based on the following interpretation of cut-off points: small (r < .20), medium (r < .40), large (r > .40).

Research Results

The results are presented below following the successive examination of the three research questions.

Independent Variables of S&T Affiliation Self-Recognition

To address RQ1, we first examined the three independent variables related to S&T affiliation self-recognition (STAS-R) (become a scientist, get a job in technology, choose an S&T subject). They connect the RoseS database with

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the SIC core, describing slightly diverse students' intentions or decisions to participate in science and displaying diverse response formats. The distribution of responses across the three STAS-Rs is presented in Table 2.

Table 2

Distribution of Responses Across the Three Independent Variables of S&T Affiliation Self-Recognition (STAS-R)

Answers	*n*	%	Valid %	Cumulated %	Collapsed %
STAS-R item: **I would like to become a scientist**					
1 Disagreement	775	40.6	47.9	47.9	68.3*
2	330	17.3	20.4	68.3	
3	310	16.2	19.1	87.4	
4 Agreement	204	10.7	12.6	100.0	31.7**
Total	1619	84.8	100.0		
Missing	290	15.2			
STAS-R item: **I would like to get a job in technology**					
1 Disagreement	650	34.0	40.0	40.0	62.6*
2	368	19.3	22.6	62.6	
3	352	18.4	21.7	84.3	
4 Agreement	255	13.4	15.7	100.0	37.4**
Total	1625	85.1	100.0		
Missing	284	14.9			
STAS-R item: **If next year you have to choose to study between a science or technology subject and a different subject, what would you decide?**					
Science	594	31.1	35.0	35.0	
Another	334	17.5	19.7	54.7	
It depends	768	40.2	45.3	100.0	
Total	1696	88.8	100.0		
Missing	213	11.2			

*Collapsed percent of answers choosing either of the two points of disagreement (1 or 2).
**Collapsed percent of answers choosing either of the two points of agreement (3 or 4).

The independent variable 'I would like to become a scientist' (hereinafter "become a scientist") has a majority response rate at the two points of disagreement (68.3%), with the highest point of disagreement (1) accounting for nearly half of all responses (Table 2). The weighted average is below 2 (M = 2.0; SD = 1.1).

Similarly, the independent variable 'I would like to get a job in technology' (hereinafter "job technology") has a majority response rate of disagreement (62.6%), with the highest level of disagreement (1) accounting for 40% of the responses (Table 2). Its weighted average is slightly above 2 (M = 2.1; SD = 1.1).

Finally, the variable "Choose to study between a science or technology subject and a different subject" (hereinafter "choose an S&T subject") shows a majority of undecided responses ("it depends" 45.3%). Slightly over one-third (35.0%) choose the S&T subject, while one-fifth choose a different subject (19.7%).

Overall, the results of STAS-R variables show that the proportion of secondary school students willing to pursue S&T studies ranges from 31% to 38%. This suggests that the rate slightly depends on the variable's content (the question asked)—whether it is scientifically oriented (becoming a scientist or choosing a S&T subject) or technologically job-oriented (getting a job in technology).

Analysis of the Dependent Variables

This section addresses the RQ2 through the statistical analysis that compares the 167 dependent variables (RoseS-Q items) between the acceptance and rejection groups drawn from the STAS-R variables. The distributions

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of these variables did not meet the normality and homogeneity of variances criteria. As a result, the Mann-Whitney non-parametric test was used to calculate statistical significance along with the effect size of the differences (Cohen's r) to compare the groups of the independent STAS-R variables. The results of these comparisons constitute the key findings for answering the research questions related for empirically mapping and validating the theoretical SIC.

The answers to the third independent variable ("choose an S&T subject") generated three groups (science, another, depends). The non-parametric Kruskal-Wallis test and the ES statistic (epsilon-squared) were applied to identify items with relevant global differences, as well as pair comparisons. The latter showed that the differences between the "depends" group and the other two groups were small: the differences between the "depends" group and the "another" group were nonsignificant ($p > .05$) for most dependent variables and not relevant for any of them (small ES); the differences between "depends" and "science" groups were nonsignificant ($p > .05$) in many variables, and the few relevant displayed small ES. Accordingly, the subsequent analysis focused on the differences between the two groups with firm affiliation: the group that chose "science" and the group that chose "another". Comparisons between these two groups were performed using the Mann-Whitney and Cohen *r* tests because only two groups were involved (table 3).

Table 3

Roses-Q Items That Attain Relevant Effect Size of the Differences (r > .20) Between the Two Groups of the Three Independent STAS-R Variables and Their Assignations to the Dimensions of Science Capital and Science Identity

Specific RoseS-Q items (category label and name, number and statement)	Cohen r (> .20)*			Dimensions**	
	Become a scientist°	Job in technology°	Choose S&T subject[a]	Science Capital	Science Identity
ATopics_01 Chemicals, their properties and how they react	.30	.21	.37	SL	COMP
ATopics_09 Atoms and molecules	.34	.22	.39	SL	COMP
ATopics_13 Black holes, supernovas and other spectacular objects in outer space			.21	SL	COMP
ATopics_21 Explosive chemicals	.20	.21	.21	SL	COMP
ATopics_22 Biological and chemical weapons and what they do to the human body			.25	TR	ACT
ATopics_33 Rockets, satellites and space travel		.24	.22	SL	COMP
ATopics_34 How X-rays, ultrasound, etc. are used in medicine	.26		.3	TR	ACT
ATopics_35 How a nuclear power plant functions	.21	.25	.26	TR	ACT
BJob_04 Working with machines or tools		.30		TR	ACT
BJob_07 Making, designing or inventing something		.25		TR	ACT
CTopics_01 How a cell phone works		.26		TR	ACT
CTopics_11 How emissions of carbon dioxide can affect the climate	.22		.23	TR	ACT
DEnvironment_03 Science and technology can solve all environmental problems		.20		AT	COMP
ETopics_02 The greenhouse effect and how it may be changed by humans	.21			TR	ACT
ETopics_04 How technology helps us to handle waste, garbage and sewage	.21	.30	.22	TR	ACT
ETopics_16 Renewable sources of energy from the sun and the wind etc.		.23		SL	COMP
ETopics_25 Benefits and possible hazards of gene modification (GMO) in farming	.23	.22	.2	TR	ACT
ETopics_27 Why scientists sometimes disagree	.28	.22		SL	COMP
ETopics_28 Famous scientists and their lives	.29			PER	ACT

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Specific RoseS-Q items (category label and name, number and statement)	Cohen r (> .20)*			Dimensions**	
	Become a scientist°	Job in technology°	Choose S&T subject[a]	Science Capital	Science Identity
ETopics_29 Big blunders and mistakes in research and inventions	.27	.26	.22	PER	ACT
ETopics_30 Inventions and discoveries that have changed the world	.23	.21	.24	PER	ACT
ETopics_31 Very recent inventions and discoveries in science and technology	.28	.31	.28	PER	ACT
ETopics_32 Phenomena that scientists still cannot explain			.22	SL	COMP
FClasses_01 School science is a difficult subject			.25	AT	COMP
FClasses_02 School science is interesting	.38	.22	.47	AT	COMP
FClasses_03 School science has opened my eyes to new and exciting jobs	.43	.24	.42	TR	ACT
FClasses_04 I like school science better than most other subjects	.53	.29	.56	AT	COMP
FClasses_05 The things that I learn in science at school will be helpful in my everyday life	.38	.22	.34	TR	ACT
FClasses_06 School science has made me more critical and sceptical	.38	.25	.32	TR	ACT
FClasses_07 School science has increased my curiosity about things we cannot yet explain	.37	.22	.35	TR	ACT
FClasses_08 School science has shown me the importance of science for our way of living	.37	.23	.34	TR	ACT
FClasses_09 School science has taught me how to take better care of my health	.24		.22	TR	ACT
FClasses_12 School science has helped me to understand sustainability solutions in my everyday life	.34	.27	.28	TR	ACT
GS&T_01 Science and technology are important for society			.24	AT	COMP
GS&T_03 Thanks to science and technology, there will be greater opportunities for future generations			.21	TR	ACT
GS&T_06 Science and technology will help to eradicate poverty and famine in the world	.24	.22		TR	ACT
GS&T_07 Science and technology can solve nearly all problems	.25	.24	.24	AT	COMP
GS&T_08 Science and technology are helping the poor	.23	.23		TR	ACT
GS&T_12 We should always trust what scientists have to say	.26	.24		SL	COMP
HUse_02 Online resources (e.g., NASA, CERN…)	.21			MED	ACT
HUse_06 Computer games		.20		MED	ACT
HUse_07 Programming and coding		.24		MED	ACT
HUse_08 Digital fabrication tools (e.g., 3D-printers & Laser cut)		.20		MED	ACT
HUse_09 Microcontrollers (e.g., Arduino, Mindstorms…)		.20		MED	ACT
IExperiences_03 Visit a science centre			.22	NFA	ACT
IExperiences_11 Play computer games		.21		MED	ACT

° Two groups compared: the group of *Agree* responses (collapsing answers 3 and 4 of the Likert format) and the group of *Disagree* responses (collapsing responses 1 and 2 of the Likert format).
[a] Two groups compared: the group that chooses the S&T subject and the group that chooses another subject.
* r: Cohen biserial correlation.
** Dimensions of human capital: scientific literacy (SL); attitudes related to science (AT); transferability (TR); media consumption (MED); knowledge of scientific persons (PER); non-formal activities (NFA). Components of science identity: competence (COMP); action (ACT)

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Table 3 shows the RoseS items that reached relevant differences (*r* > .20) in the comparisons between two groups of the STAS-R variables ("become a scientist," "job technology," and "choose an S&T subject"). The latter focuses on comparing the two groups with firm self-recognition: "science" and "another."

The overall comparisons between the two collapsed agreement and disagreement groups of the independent variable "become a scientist" revealed that 115 RoseS-Q variables showed statistically significant differences (*p* < .01), and that 28 variables exceeded the ES threshold (*r* > .20). However, only one variable (FClasses_04 I like science better than most other school subjects) achieved a large ES (*r* > .50).

Comparisons between the two collapsed groups of agreement and disagreement with the independent variable "job technology" showed that 128 RoseS-Q variables achieved a statistically significant difference (*p* < .01) between these two groups, and 33 of them exceeded the threshold (*r* > .20) of the ES. However, none of these variables reached a very large ES (*r* > .50).

Comparisons between the two "choose an S&T subject" groups indicated that 85 RoseS-Q variables reached a statistically significant difference (*p* < .01) between these two groups, and 29 of them exceeded the ES threshold (*r* > .20), although only one (I like science better than most other school subjects) reached a large ES (*r* > .50).

Analysis of the Relevant Empirical Traits for Each Independent Variable

The analysis of empirical traits reveals quantitative consistency in the results for mapping SIC. Approximately 100 traits (dependent variables) showed significant differences (*p* < .01) between the two acceptance and rejection groups of the three independent STAS-R variables, and this set is mostly identical across the three STAS-R. Similarly, the number of traits (28, 33, and 29, as shown in Table 3) reaching a relevant ES (*r* > .20) for the three STAS-R variables are also remarkably similar and consistent with each other (Table 3).

The independent variable, "become a scientist," presents 28 traits that empirically show relevant differences (r > .20) between the acceptance and rejection groups (Table 3). Half of these SIC-relevant features refer to curricular topics (14), with the largest differential interest observed in atoms and molecules, chemical products, and applications in medicine. Almost all the items of the school science class category (9 out of 10) are also relevant features, where the following three achieve the largest differences: I like science more than other subjects; Science classes have made me more critical and sceptical; Science has opened my eyes to new and exciting jobs. The remaining relevant traits of this first variable show the smallest differences and correspond to the S&T image category (e.g., S&T will help eradicate poverty and hunger in the world) and the frequency of digital media usage in science classes.

The "job technology" independent variable displays 33 traits with relevant differences (*r* > .20) between the acceptance and rejection groups (Table 3). Over one-third of these relevant features of SIC (13) refer to curricular topics, with the largest differential interest observed in topics on modern inventions and discoveries and technology as an aid to waste, garbage, and wastewater management. The fourth part of the relevant features consists of almost all the items related to school science classes (8 out of 10), among which the following stand out: Science is an interesting school subject; Science has opened my eyes to new and exciting jobs; I like science more than other subjects. In addition, four traits related to the S&T image (S&T can solve almost every problem; We should trust what scientists say), and four traits of frequency of digital media use in science classes (focused on programming and coding) also contribute to this technological aspect of SIC. The rest of the traits that complete this technological identity contain two items about a future job (Working with machines and tools; Making, designing, or inventing something), one item of environmental attitudes (S&T can solve all environmental problems), and another item of extracurricular experiences (Digital games to learn science).

The "choose an S&T subject" independent variable displays 29 features with empirically relevant differences (*r* > .20) between students who choose the S&T subject and those who choose another subject (Table 3). Half of these relevant SIC features refer to curricular topics (15), with the greatest differential interest observed in topics on atoms and molecules, chemical products, and applications in medicine. The other half of the relevant features consist of all the items of the school science classes (10), among which the following stand out: I like science more than other subjects; Science is an interesting subject; Science has opened my eyes to new and exciting jobs; Science made me more critical and sceptical. The remaining four traits correspond to three traits of the S&T image, highlighting that S&T is important to society and can solve almost all problems, and, finally, the effectiveness of learning science from visits to a science centre.

Further, these results not only provide the empirically relevant SIC traits based on the STAS-R variables (become a scientist, job in technology, choose an S&T subject) but also highlight mutual consistency. Firstly, the relevant SIC traits in the first (become a scientist) and third variables (choose an S&T subject) are practically identical to

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each other, with 75% of the traits being common to these two independent variables. Secondly, another aspect of consistency in the SIC profiles is that the relevant traits obtained in the second variable (job in technology) differ from the SIC traits generated by the other two variables in ten traits. These ten traits are exclusive of "job in technology" and are not relevant for the other two variables. In addition, the consistency is reinforced by the fact that the contents of these ten traits consistently correspond to technological topics (problem-solving, digital media, inventions, machines, designing, inventing, etc.).

Thirdly, the items with the largest ES in the differences, indicative of greater statistical power to differentiate between STAS-R acceptance and rejection, also show consistency across the three STAS-R variables. For instance, the item with the largest ES (I like science more than most other school subjects) is the same for "become a scientist" (r = .56) and "choose an S&T subject" (r = .53). Further, its content (liking science subjects) is obviously required (consistent) to become a scientist and choose an S&T subject. Similarly, the largest ES on "job in technology" (r = 0.31) is associated with the interest in modern inventions and discoveries in S&T, which is also consistent with the technological content of getting a job in technology.

Fourth, the differences between the three SIC profiles are quantitative and qualitative (Table 3). The quantitative difference refers to the magnitude of the ES of the differences between profiles. The SIC profiles of the variables "become a scientist" and "choose an S&T subject" present 10 items with medium to high ES (.30 < r < .54). However, the SIC profile of the variable "job technology" is lower, as its largest ES (modern inventions and discoveries in S&T) is hardly moderate (r = .31).

The main qualitative difference between the three SIC profiles, empirically generated from the STAS-R, lies in the content of the items with the highest ES differences in each profile. On the one hand, the SIC profiles in the variables "become a scientist" and "choose an S&T subject" are practically identical in their 10 most relevant items. The common core consists of seven items from science classes and two topics (chemicals and atoms and molecules), and the difference comes down to a single trait (understanding sustainable solutions in my everyday life, for the SIC in "become a scientist," and applications in medicine in "choose an S&T subject"). On the other hand, the single trait of the SIC profile for "job technology" with the highest ES (modern inventions and discoveries in S&T) has nothing to do with the previously mentioned traits.

This set of relevant traits defines the students' SIC regarding the groups accepting/rejecting the S&T affiliation along the three STAS-R variables (become a scientist, job in technology, and choose an S&T subject), which is the key feature of SIC. Thus, the traits that generate the relevant differences in S&T affiliation specify the SIC map (Table 3). Overall, the SIC map comprises 46 different traits: 18 are common to the three STAS-R variables, 8 are shared by two variables, and the remaining 20 appear in only one variable. This specification of the SIC is robust because the traits are supported by a stringent criterion (r > .20; p < .00000001) for identifying the differences between students who express acceptance and those who express rejection.

Analysis of the Traits of the Map and the Dimensions of Science Identity and Capital

This section addresses the RQ3 by qualitatively analysing the consolidated traits for the SIC map in relation to the SIC theoretical dimensions and components. The 18 traits shared by the three STAS-R variables form the core of the SIC map because they are common to all three variables and further represent most traits (between 64% and 55%) within each variable. Further, this commonality of the SIC core is independent of the variable or question used to define students' affiliation with S&T, and this independence represents a significant finding.

The SIC core composition consists of nine S&T topics, eight items related to science classes, and a single trait of the S&T image (S&T can solve almost all problems). Considering the content of each item and the dimensions of science capital, two elements of the SIC core may correspond to scientific literacy (SL), three to science-related attitudes, 10 to transferability, and three to knowing scientific persons. From the perspective of the science identity components, five traits belong to competence and 13 to action.

In regard of the relevant traits shared by two of the STAS-R variables (8), almost all (7) are generated by "become a scientist" and are shared with "job in technology" (4) and "choose an S&T subject" (3). Considering the SIC dimensions, these traits spread on scientific literacy and transferability and on competence and action.

Another finding reveals that the traits that are relevant only in one variable (20) mostly belong to "job in technology" (9) and "choose an S&T subject" (8), whereas only three traits belong to "become a scientist." The nine traits that are only relevant in the specific profile of "job in technology" highlight again the consistency between variables and relevant traits, as they all emphasize technological aspects. These traits fall into the categories of digital technology use (5), features of future job (using machines and designing and inventing), and technologi-

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cal topics (cell phones and renewable energies). Considering the dimensions of SIC, these traits mainly spread on transferability and action components.

On the other hand, the eight traits that are only relevant in the specific profile of "choose an S&T subject" correspond to the image of S&T (2), interest in spectacular space topics, unexplained phenomena, and biological and chemical weapons. Further, this is the unique profile that includes a non-formal experience (visiting a science centre) and the perceived difficulty of learning science. Once again, it appears consistent that the subject difficulty, spectacular content, and the importance of science for future opportunities may lead to differences when choosing an S&T subject.

In summary, the SIC map identifies most core traits that are independent of the type of STAS-R requested, along with another set of traits that are specific to each variable. The technological items generated by "job in technology" stand out for their coherence with technology-related issues and further support the map's consistency. The traits of the SIC map spread across all the dimensions of science capital and the components of science identity.

Discussion

Science identity and science capital (SIC) have been proposed and researched as explanatory lenses of S&T affiliation within a sociocultural framework, which emphasizes analyses focused on the intersectionality of socially important variables, such as gender, ethnicity, or social class (Archer et al., 2015, 2023; Carlone & Johnson, 2007; DeWitt, Archer et al., 2013).

As the qualitative and sociocultural status of SIC remains somewhat distant from school science education, some researchers have suggested a more concrete mapping of SIC (Butterfield & Marshall, 2022; Taconis, 2022). Thus, this study contributes a SIC map that is derived from a survey with a science education approach and is independent of mainstream qualitative and sociocultural SIC research (DeWitt & Archer, 2015; Moote et al., 2021).

The common key point of SIC research is the S&T affiliation or membership (acceptance or rejection), which is the third component of science identity (Carlone & Johnson, 2007) and the explanatory aim of science capital (Archer et al., 2015). Accordingly, this study operationalizes affiliation through STAS-R items of the survey ("become a scientist," "get a job in technology," and "choose an S&T subject"), thereby broadening the scope of the map. The overall answer to the first research question (RQ1) indicates that students' S&T engagement ranges from 31% to 38%, which is higher than the percentages reported by López et al. (2019).

The comparison between the acceptance/rejection groups generated by the STAS-R variables enables the identification of the specific traits that constitute SIC and establishes their relationships to the theoretical dimensions proposed for SIC (Archer et al., 2015; Carlone & Johnson, 2007). A rigorous criterion (Cohen's $r > .20$) provides the basis for answering the second research question (RQ2) by identifying a 46-trait set that operationalizes the SIC map and offers a measure of the trait relevance.

The map includes an 18-trait subset, common and predominant across all three STAS-R variables, and a 28-trait subset, which is not shared by all three STAS-R variables. The former constitutes the key core of the SIC map, as it is independent of the type of recognition (become a scientist, job in technology, or subject choice) that generated it. The latter shows internal consistency with respect to its generative variable and discrimination in relation to the other variables, providing additional support and sensitivity to the SIC map (Butterfield & Marshall, 2022; Kim et al., 2018). In summary, this map contributes educationally relevant information, and its relationship to SIC dimensions supports its empirical validation, which may help advance the research field (Archer et al., 2023).

Finally, the assignment of the relevant traits of the SIC map to the theoretical dimensions of SIC addresses the third research question (Rq3) and completes the proposal. The map traits are structured across the dimensions of science capital: scientific literacy (9 traits), attitudes related to science (6 traits), transferability (20), media consumption (6), knowing scientists (4), and non-formal activities (1) (Archer et al., 2015). Regarding science identity, 15 map traits correspond to the competence dimension and 31 to the action dimension (Carlone & Johnson, 2007). Overall, the empirical SIC map contributes to reinforcing the role of SIC as the lens for exploring the participation in S&T by embodying SIC through specific traits that are useful not only for SIC research but also for science education and science teachers.

Conclusions and Implications

This study contributes new, relevant, and specific traits that map the dimensions of science capital and the components of science identity, adding to SIC some educational value for science education and science teachers.

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For instance, scientific literacy is operationalized through interest in scientific knowledge (e.g., atoms and molecules), knowledge about science (e.g., scientists sometimes disagree), and citizen knowledge (e.g., renewable sources of energy). Similarly, attitudes toward science (e.g., school science is interesting), transferability (e.g., greenhouse effect and how it may be changed by humans), media consumption (e.g., online resources), knowledge of scientific persons (e.g., famous scientists and their lives), non-formal activities (e.g., visit a science centre) are operationalized by a set of specific educational traits. Another similar novelty is the specific map of science identity dimensions, such as competence (e.g., science and technology are important for society) and action (e.g., school science has helped me to understand sustainability solutions in my everyday life).

The main consequence for research and educational practice is that the set of relevant traits can be used to teach and assess the individuals' SIC at a particular time point as well as to analyse SIC trajectories over time. Furthermore, it is worth noting that the categories of interest in science topics and the science classes dominate the relevant SIC traits, each suggesting direct implications for school science education and teachers. Overall, teachers should focus on improving students' SIC traits by developing them within the classroom to make them more engaging and effective, especially for less engaged students. For instance, the trait "School science has opened my eyes to new and exciting jobs" achieved the highest relevance; thus, teachers should focus on prioritizing the job-oriented aspects of science learning. In addition, the findings point out that the instrument could be reduced to the 46 relevant SIC items, making it more manageable and practical for research and teaching.

The limitations of this study are mainly derived from its independent design (based on the RoseS-G instrument) in relation to mainstream sociocultural research on SIC. However, this limitation can also be considered a strength, as the independence contributes to reinforcing this validation and to complementing the sociocultural approaches. However, it is noteworthy that the RoseS-G lacks items about parental qualifications and talking about science, which restricts two SIC dimensions in the study. Another qualitative limitation relates to the scientific literacy dimension of science capital, which is here interpreted as students' interest in S&T topics (chemicals, atoms and molecules, etc.). Nonetheless, the centrality of interest for S&T learning and aspirations does diminish its importance. Finally, gender analyses of the SIC map are omitted to avoid exceeding the study's length.

The findings of this study provide valuable opportunities for further research and practical application. Science teachers should explicitly address the relevant traits of the SIC map (e.g., relevant topics, perceptions of science classes) as a pedagogy to positively enhance and develop their students' SIC. On the other hand, the reduced list of relevant traits may be used in research as a SIC assessment tool, either to capture an instant snapshot or to follow developmental trajectories. From this instrumental view, new research challenges focus on examining issues of applicability, validity, and reliability.

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Declaration of Interest

The authors declare no competing interest.

References

Archer Ker, L., DeWitt, J., Osborne, J. F., Dillon, J. S., Wong, B., & Willis, B. (2013). *ASPIRES Report: Young people's science and career aspirations, age 10 –14*. King's College London.

Archer, L., Dawson, E., Dewitt, J., Seakins, A., & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending Bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*, *52*(7), 922–948. https://doi.org/10.1002/tea.21227

Archer, L., Godec, S., & Moote, J. (2022). "My love for it just wasn't enough to get me through": A longitudinal case study of factors supporting and denying black British working-class young women's science identities and trajectories. In H. T. Holmegaard & L. Archer (Eds.), *Science identities: Theory, method and research* (pp. 23–45). Springer International Publishing.

Avraamidou, L., & Schwartz, R. (2021). Who aspires to be a scientist/who is allowed in science? Science identity as a lens to exploring the political dimension of the nature of science. *Cultural Studies of Science Education*, *16*(2), 337–344. https://doi.org/10.1007/S11422-021-10059-3/FIGURES/2

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Butterfield, S. M. J., & Marshall, K. B. (2022). Using qualitative metasynthesis to understand the factors that contribute to science identity development across contexts in secondary and post-secondary students from underrepresented groups. In H. T. Holmegaard & L. Archer (Eds.), *Science identities: Theory, method and research* (pp. 273–298). Springer International Publishing. https://doi.org/10.1007/978-3-031-17642-5

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*(8), 1187–1218. https://doi.org/10.1002/TEA.20237

Cleaves, A. (2005). The formation of science choices in secondary school. *International Journal of Science Education*, *27*(3), 471–486. https://doi.org/10.1080/0950069042000323746

DeWitt, J., & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education*, *37*(13), 2170–2192. https://doi.org/10.1080/09500693.2015.1071899

DeWitt, J., Archer, L., & Osborne, J. (2013). Nerdy, brainy and normal: Children's and parents' constructions of those who are highly engaged with science. *Research in Science Education*, *43*(4), 1455–1476. https://doi.org/10.1007/S11165-012-9315-0/METRICS

DeWitt, J., Archer, L., & Osborne, J. (2014). Science-related aspirations across the primary–secondary divide: Evidence from two surveys in England. *International Journal of Science Education*, *36*(10), 1609-1629. https://doi.org/10.1080/09500693.2013.871659

DeWitt, J., Osborne, J., Archer, L., Dillon, J., Willis, B., & Wong, B. (2013). Young children's aspirations in science: The unequivocal, the uncertain and the unthinkable. *International Journal of Science Education*, *35*(6), 1037–1063.

Dierks, P. O., Höffler, T. N., & Parchmann, I. (2014). Profiling interest of students in science: Learning in school and beyond. *Research in Science & Technological Education, 32*(2), 37–41. https://doi.org/10.1080/02635143.2014.895712

European Commission (2004). *Europe needs more scientists*. Office for Official Publications of European Communities.

European Commission (2012). *Rethinking education: Investing in skills for better socio-economic outcomes. COM(2012) 669*. European Commission.

Everis (2012). *Factores influyentes en la elección de estudios científicos, tecnológicos y matemáticos. Visión de los estudiantes de 3º y 4º de ESO y Bachillerato* [Factors influencing the choice of scientific, technological and mathematical studies. Perspectives of students in 3rd and 4th year of ESO and Baccalaureate]. Author. http://www.everis.com/spain/WCLibraryRepository/References/estudio vocaciones.pdf

Fundación Española para la Ciencia y la Tecnología. (2023). *Encuesta de percepción social de la ciencia y la tecnología en España 2022* [Survey on social perception of science and technology in Spain 2022]. Author. https://www.fecyt.es/es/noticia/encuestas-de-percepcion-social-de-la-ciencia-y-la-tecnologia-en-espana

Fensham, P. J. (2009). Real-world contexts in PISA science: Implications for context-based science education. *Journal of Research in Science Teaching*, *46*(8), 884–896. https://doi.org/10.1002/TEA.20334

Hernández Armenteros, J. (2010). *La universidad española en cifras* [The Spanish university in figures]. Conferencia de Rectores de las Universidades Españolas (CRUE). http://www.crue.org/export/sites/Crue/Publicaciones/UEC2010VOLI.pdf

Jenkins, E. W., & Nelson, N. W. (2010). Important but not for me: Students' attitudes towards secondary school science in England. *Research in Science & Technological Education, 23*(1), 41–57. https://doi.org/10.1080/02635140500068435

Jidesjö, A., Oskarsson, M., & Westman, A-K. (2020). ROSES handbook: Introduction, guidelines and underlying ideas. *Utbildningsvetenskapliga Studier 2020:1*. Mid Sweden University. http://www.miun.se/roses

Kim, A. Y., & Sinatra, G. M. (2018). Science identity development: An interactionist approach. *International Journal of STEM Education*, *5*, Article 51. https://doi.org/10.1186/s40594-018-0149-9

Kim, A. Y., Sinatra, G. M., & Seyranian, V. (2018). Developing a STEM identity among young women: A social identity perspective. *Review of Educational Research, 88*(4), 589–625. https://doi.org/10.3102/0034654318779957

López Rupérez, F., García García, I., & Expósito Casas, E. (2019). Performance in science, epistemic conceptions, and S&T vocations in Spain's autonomous communities: Evidence from PISA 2015, improvement policies, and practices. *Revista Española de Pedagogía*, *77*(272), 5–27. https://doi.org/10.22550/REP77-1-2019-09

Lyons, T., & Quinn, F. (2010). *Choosing science. Understanding the declines in senior high school science enrolments*. University of New England. http://simerr.une.edu.au/pages/projects/131choosingscience.pdf

Manstead, A. S. R., Hewstone, M., Fiske, S. T., Hogg, M. A., Reis, H. T., & Semin, G. R. (Eds.), (1995). *The Blackwell encyclopaedia of social psychology*. Blackwell.

Moote, J., Archer, L., DeWitt, J., & MacLeod, E. (2021). Who has high science capital? An exploration of emerging patterns of science capital among students aged 17/18 in England. *Research Papers in Education*, *36*(4), 402–422. https://doi.org/10.1080/02671522.2019.1678062

Mullis, I. V. S., Martin, M. O., von Davier, M. (2021). *TIMSS 2023 assessment framework*. Boston College. https://timssandpirls.bc.edu/index.html

National Academies of Sciences, Engineering, and Medicine. (2016). *Science literacy: Concepts, contexts, and consequences*. The National Academies Press. https://doi.org/10.17226/23595

OECD (2016a). *PISA 2015 results (Vol. I): Excellence and equity in education*. OECD Publishing. http://dx.doi.org/10.1787/9789264266490-en

OECD (2016b). *PISA 2015 results (Vol. II): Policies and practices for successful schools*. OECD Publishing. http://dx.doi.org/10.1787/9789264267510-en

OECD (2019). *PISA 2018 science framework*. OECD Publishing. https://doi.org/10.1787/f30da688-en

Olsen, R. V., Prenzel, M., & Martin, R. (2011). Interest in Science: A many-faceted picture painted by data from the OECD PISA study. *International Journal of Science Education, 33*(1), 1–6. https://doi.org/10.1080/09500693.2011.518639

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections. A report to the Nuffield Foundation*. Nuffield Foundation.

Palmer, T. A., Burke, P. F., & Aubusson, P. (2017). Why school students choose and reject science: A study of the factors that students consider when selecting subjects. *International Journal of Science Education*, *39*(6), 645–662. https://doi.org/10.1080/09500693.2017.1299949

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: A systematic review of 12 years of educational research. *Studies in Science Education*, *50*(1), 85–129. https://doi.org/10.1080/03057267.2014.881626

Rodríguez González, E. (2011). Ciencia y tecnología: ¿En qué piensan los jóvenes 2.0? [Science and technology: What do 2.0 young people think about?] In Fundación Española para la Ciencia y la Tecnología (Ed.), *Percepción Social de la Ciencia y la Tecnología en España* [Social perception of Science and Technology in Spain 2022] (pp. 203–235). Author.

Sjøberg, S., & Schreiner, C. (2019). *ROSE (The relevance of science education): The development, key findings and impacts of an international low cost comparative project. ROSE Final Report, Part 1*. University of Oslo.

Taconis, R. (2022). Representing S&T identities as pragmatic configurations. In H. T. Holmegaard & L. Archer (Eds.), *Science identities: Theory, method and research* (pp. 299–332). Springer International Publishing. https://doi.org/10.1007/978-3-031-17642-5

United Nations (2015). *Transforming our world: The 2030 agenda for sustainable development*. https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/291/89/PDF/N1529189.pdf?OpenElement

Vázquez, A., & Manassero, M.A. (2008). El declive de las actitudes hacia la ciencia de los estudiantes: un indicador inquietante para la educación científica [The decline of students' attitudes toward science: A disturbing indicator for science education]. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias, 5*(3), 274-292. http://dx.doi.org/10.25267/Rev_Eureka_ensen_divulg_cienc.2008.v5.i3.03

Vázquez, Á., & Manassero, M. A. (2009a). Factores actitudinales determinantes de la vocación científica y tecnológica en secundaria [Attitudinal factors determining the scientific and technological vocation in secondary education]. *Cultura y Educación*, *21*(3), 319–330. https://doi.org/10.1174/113564009789052280

Vázquez, Á., & Manassero, M. A. (2009b). Patrones actitudinales de la vocación científica y tecnológica en chicas y chicos de secundaria [Attitudinal patterns of scientific and technological vocation in high school girls and boys]. *Revista Iberoamericana de Educación*, *50*(4), 1–15. https://doi.org/10.35362/RIE5041879

Zamora, J. (2004). *¿Hay una 'crisis de vocaciones' científico-tecnológicas? El tránsito de la Enseñanza Secundaria a la Universidad* [Is there a scientific-technological 'vocation crisis'? The transition from secondary education to university]. Fundación Española para la Ciencia y la Tecnología.

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EFFECTS OF PSYCHOLOGICAL CAPITAL AND COGNITION ON STEM LEARNING IN IOT SMART ENERGY-SAVING PROJECTS

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Abstract. *Project-based learning (PBL) plays a critical role in fostering interdisciplinary integration within science, technology, engineering, and mathematics (STEM) education. However, its complexity often hinders students' ability to apply knowledge and solve problems, particularly in environments that lack psychological and cognitive support. This study aims to address these challenges by constructing a STEM education model centered on PBL and examining the interactions among STEM psychological capital (SPC), problem-solving skills (PS), STEM cognition (SC), and STEM project-based learning performance (SP). In total, 230 seventh-grade students participated in a STEM project-based activity themed "Internet of Things (IoT) Smart Energy-Saving House." Data were collected through questionnaires and performance assessments. Partial least squares structural equation modeling (PLS-SEM) was used to analyze the interactions. By validating the interplay among psychological capital, cognition, and problem-solving abilities in STEM-PBL contexts, this study identifies the critical role of SPC, PS, and SC in enhancing students' SP outcomes and underscores the necessity of integrating psychological support and cognitive development into STEM curricula. Furthermore, the findings provide a novel framework for bridging the gap between theoretical knowledge and practical application, offering valuable insights for future research and educational design.*

Keywords: *project-based learning, STEM cognition, problem-solving skills, psychological capital, STEM education, partial least square-structural equation modeling*

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Introduction

Science, technology, engineering, and mathematics (STEM) education is widely recognized as an effective approach to prepare students for the challenges of the 21st century. By encompassing multiple disciplines, STEM education can cultivate critical thinking, innovation, and reasoning skills. However, as demand for STEM education continues to grow, educators and researchers face the challenge of effectively implementing teaching strategies within this complex and interdisciplinary framework. Despite the potential of traditional STEM education, significant issues persist in engaging students, fostering meaningful learning, and assessing educational outcomes, which makes these concerns central to the field (Sulaiman et al., 2023).

A meta-analysis has revealed that project-based learning (PBL) is one of the most effective methods for enhancing learning outcomes (Suciana et al., 2023). PBL has gained traction in STEM education due to its ability to foster innovation, critical thinking, and problem-solving skills (PS) as students attempt to address real-world problems. However, few studies have explored the specific mechanisms through which STEM project-based learning (STEM-PBL) promotes learning, particularly its role in activating cognitive and skill-related processes. From the perspective of cognitive activation theory, Lamb et al. (2015) have suggested that the success of STEM learning may rely on an interplay between emotional and cognitive factors. Creating such interplay activates cognitive processes, enhancing the ability of students to apply and integrate disciplinary knowledge. The interaction between cognition and other critical elements also deepens understanding of STEM disciplines and enables students to deploy essential skills when confronted with complex problems.

Consequently, STEM education aims to equip students with the skills necessary to address complex interdisciplinary challenges, yet it simultaneously presents urgent difficulties. While the integration of science, technology, engineering, and mathematics offers students diverse opportunities for learning, many struggle to connect abstract concepts with real-world applications, resulting in a disconnect between learning and practice. Addressing this gap requires a deeper exploration of the interplay between psychological

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and cognitive factors in the learning process. Therefore, elements from the Cognition-Priming Model (CPM) and STEM psychological capital (SPC) have been integrated to develop an innovative framework for elucidating the mechanisms underlying student success in STEM-PBL.

A CPM can serve as a robust framework for understanding cognitive processes, specifically the interactions between external stimuli and internal cognition at the core of learning. Lamb et al. (2014) have noted that embedding specific contexts or activities within educational design can effectively trigger cognitive processes, helping students to apply knowledge in analysis and problem-solving tasks. These cognitive processes often manifest externally in the form of behaviors or outcomes, such as test responses or project performance (Bogg & Finn, 2010).

SPC has been incorporated into a CPM as an extended framework. SPC includes critical psychological traits, including passion, perseverance, hope, optimism, and resilience, which play a pivotal role in helping students navigate STEM learning challenges (Blanchette & Richards, 2010). This research hypothesized that SPC would enhance learner capacity to respond to external learning stimuli, for example by facilitating more active engagement in challenging tasks or leveraging relevant background knowledge, thereby supporting cognitive priming processes and consequently improving PS and learning performance. Furthermore, embedding these cognitive and psychological mechanisms within practical, interdisciplinary contexts—such as technology-driven solutions to real-world problems—could amplify their impact, aligning STEM education with broader societal needs.

Given the increasing global demand for sustainable education practices in STEM, particularly in regions facing energy efficiency challenges, there is a need for structured frameworks that incorporate both cognitive and psychological dimensions. While project-based learning has been widely recognized as an effective pedagogical approach, its implementation often lacks a systematic model that fosters interdisciplinary problem-solving and resilience. By integrating IoT technology and psychological support, this study proposes a replicable framework that educators can adapt to cultivate essential 21st-century skills while addressing sustainability challenges.

Thus, this study aimed to construct and validate a STEM-PBL model that examined the interplay among SPC, PS, SC, and SP. The research provided empirical insights into the cognitive and psychological mechanisms underlying students' project-based learning performance.

Literature Review

Conceptualization of STEM Psychological Capital

Psychological capital (PC) can be defined as a positive psychological developmental state and traditionally encompasses four core dimensions: self-efficacy, hope, optimism, and resilience (Luthans et al., 2007). According to the broaden-and-build theory (Fredrickson, 2001), positive emotional experiences expand thought-action repertoires and build enduring psychological resources. PC is considered a measurable, developable, and effective resource; it is known to enhance academic and organizational performance and to play a critical role in academic success (Avey et al., 2011; Li et al., 2023; Ortega-Maldonado & Salanova, 2018).

As STEM education continues to evolve, learners face increasingly complex challenges including long-term commitment, integration of multidisciplinary knowledge, and demand for advanced PC. Sweetman et al. (2011) found that PC has a direct and significant effect on creativity and suggested that the integrative role of PC is crucial in cognitive tasks, particularly those involving complex problem-solving. PC enhances focus, strategic thinking, and goal-oriented behaviors, all of which are essential for addressing such challenges. In general, creativity and complex problem-solving share similar cognitive characteristics: both require substantial psychological resources, and positive psychological states are known to enhance problem-solving performance (Luthans et al., 2011).

Moreover, Luo et al. (2024) explored how STEM capital, its significant influence on learners' academic performance and aspirations in STEM-related disciplines. Their findings indicated that STEM capital has significant effects on long-term commitment to achieving STEM-related goals, confirming the importance of social support and learning resources to STEM capital, but the study did not sufficiently explore how the intrinsic psychological traits of learners affect PBL. Considering that PBL requires learners to demonstrate a high level of autonomy and sustained engagement, it is proposed that the conventional PC should be further refined to address the specific demands of STEM-PBL contexts.

Therefore, this framework retains the core constructs of traditional PC (hope, optimism, resilience) while introducing two additional constructs – passion and perseverance – to comprehensively capture the psychological needs and behavioral expressions of students engaged in STEM-PBL. Self-efficacy remains central to traditional PC and plays a vital role in helping learners tackle specific challenges in STEM contexts (Schunk & DiBenedetto, 2020),

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but a sole focus on self-efficacy may not fully account for the emotional drive and behavioral persistence among learners as they engage in the long-term processes and multi-stage challenges involved in PBL.

Compared to existing research, this study is the first to incorporate passion and perseverance into the PC framework and integrate the CPM to examine their unique roles in STEM-PBL. This innovation expands the theoretical application of PC, also addresses a critical gap in PBL research concerning the impact of students' psychological traits. Passion is linked with deep interest and intrinsic motivation among learners as they pursue goals, particularly those related to real-world problems. Perseverance is linked with consistent effort and long-term engagement, particularly as learners engage in iterative trial-and-error processes (Duckworth et al., 2007). These attributes enhance the adaptability of the PC framework to the specific demands of STEM-PBL, offering a more nuanced understanding of learner behaviors.

Passion

Passion is linked with a learner's intrinsic motivation and sustained interest in achieving a goal. It is critical to maintaining long-term engagement in solving complex problems; particularly within STEM education, addressing real-world challenges often demands strong intrinsic drive. Duckworth et al. (2007) found that passion and perseverance are significant predictors of academic achievement and success in other fields. Passion encourages learners to be more autonomous and creative in projects while sustaining learning motivation over time. Vallerand (2015) noted that passion fosters psychological adaptability, helping learners remain consistently committed to long-term goals. This trait is particularly vital in PBL environments that require iterative trial and error as well as prolonged focus. The combination of passion and learning objectives encourages learners to actively engage in the learning process and to demonstrate higher levels of creativity and resilience in challenging situations. Learners with passion achieve superior long-term performance, particularly when tackling demanding tasks that require innovative solutions and unwavering dedication.

Perseverance

Perseverance is linked with determination and consistent effort to overcome learning challenges, especially within STEM learning environments that require iterative trial-and-error and continuous improvement. Some research suggests a modest direct correlation between perseverance and academic achievement, but the long-term effects appear to be significant. Perseverance enhances the completion rate of problem-solving tasks and the quality of learning, particularly in PBL. Luthans et al. (2018) reported that high-perseverance learners are better equipped to handle setbacks and challenges in the learning process, as their self-regulation and reflective abilities can deepen and integrate cognitive processes.

Hope

Hope is a psychological trait that drives learners to set goals and actively seek methods to achieve them. Snyder et al. (2002) conceptualized hope as a combination of "pathways thinking" and "agency thinking." From this perspective, high-hope learners can remain flexible in the face of challenges, continuously exploring alternative strategies to overcome obstacles. Hope is an important element of PC, significantly contributing to goal attainment and improved learning performance (Luthans et al., 2004). High-hope learners tend to set clear and challenging goals, view setbacks as opportunities for growth, and break down goals into manageable steps, resulting in greater academic success (Snyder et al., 2006). In contrast, low-hope learners often set vague or easily achievable goals, struggle with flexibility, and are prone to negativity when encountering difficulties. Hope plays a critical role in shaping goal-setting quality, coping strategies, and sustained engagement.

Optimism

Optimism refers to a tendency to attribute future outcomes to positive events, particularly when facing challenges. Peterson (2000) noted that optimists perceive difficulties as surmountable challenges and believe in their ability to find solutions. Optimism reduces psychological stress, enhances persistence, and sustains motivation in learning. In the context of STEM-PBL, optimistic learners maintain a positive attitude during iterative trial-and-error processes, ultimately achieving successful outcomes. Carver et al. (2010) found that optimism is closely linked with

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coping strategies and psychological well-being, significantly affecting performance under challenging conditions. Bertieaux et al. (2024) identified optimism as a key factor of PC, underscoring its importance in supporting STEM learners.

Resilience

Resilience refers to the ability of learners to quickly adapt and reconstruct strategies when faced with failure or difficulty. Smith et al. (2013) found that resilience helps learners manage stress in challenging situations and also to extract valuable lessons from mistakes and refine their learning strategies. In PBL contexts, resilient students are more able to adapt to uncertainties in knowledge application and tend to demonstrate creative PS during reflection and improvement; Masten (2001) identified resilience as a critical factor for maintaining adaptive functioning in adversity, with profound implications for learning and development. Resilience is generally considered a vital psychological resource (Luthans et al., 2004).

Problem-Solving Skills, STEM Cognition, and STEM Project-Based Learning Performance

One core objective of STEM education is to foster interdisciplinary problem-solving. Sternberg (2003) conceptualized PS as involving key stages such as problem identification, data collection and analysis, solution design and implementation, and reflection and improvement, forming a comprehensive learning and thinking process. This ability is particularly critical in STEM education, as students must integrate elements of mathematics, science, and technology to address diverse real-world challenges.

PS and SC are closely linked. English (2023) reported that STEM-based problem-solving promotes the development of richer disciplinary thinking in mathematics and technology-related fields, enhancing ability to integrate knowledge across disciplines. Conversely, Su (2020) noted that a lack of higher-order cognitive skills limits the ability of students to integrate STEM knowledge, thereby undermining their performance in applying this knowledge to interdisciplinary contexts. Ultimately, this deficiency can hinder their potential to develop robust problem-solving capabilities.

Lou et al. (2011) found that PBL strategies significantly improve the ability of students to integrate STEM knowledge and positively influence their attitudes about science. These findings suggest that students engaging in iterative cycles of knowledge acquisition and solution implementation may have a deeper understanding of STEM-related knowledge and also internalize related concepts for more flexible applications. This iterative process improves conceptual understanding, also equips students with the skills to achieve superior performance in project-based tasks.

The role of SC as a mediator between PS and SP further underscores its importance. SC supports the cognitive processes involved in PS and also bridges the gap between problem-solving and project-based outcomes. Stohlmann et al. (2012) noted that SC facilitates the application of abstract STEM knowledge to practical tasks, enabling students to refine their problem-solving strategies and enhance their project outcomes. This suggests that the interaction between PS and SP is strengthened when SC is effectively developed. For instance, students with a strong grasp of STEM concepts are better equipped to identify gaps in their solutions and iteratively improve their designs, leading to superior performance in PBL environments.

STEM Project-Based Learning

Thomas et al. (1999) stressed that fostering autonomous learning and practical abilities is at the core of PBL. As students engage in the process of solving real-world problems, this learning model emphasizes the transformation of theoretical knowledge into concrete solutions, promoting higher-order thinking and knowledge construction (Kokotsaki et al., 2016). PBL is particularly well-suited to STEM education, where the integration of knowledge across multiple disciplines is essential (Asghar et al., 2012; Lin & Lu, 2018). In STEM contexts, PBL provides a practical platform for students to apply disciplinary knowledge in authentic scenarios, enhancing both learning motivation and PS (Capraro et al., 2013; Pertiwi et al., 2024).

During PBL, learners go through iterative cycles of problem identification, solution design, implementation, and reflection. This process effectively promotes the development of PS. The PBL learning process requires mastering disciplinary knowledge, as well as higher levels of psychological resilience. For example, traits such as passion,

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perseverance, hope, optimism, and resilience play a crucial role in determining the quality of task completion and overall learning outcomes when students face repeated trials and challenges (Duckworth et al., 2007; Luo et al., 2024).

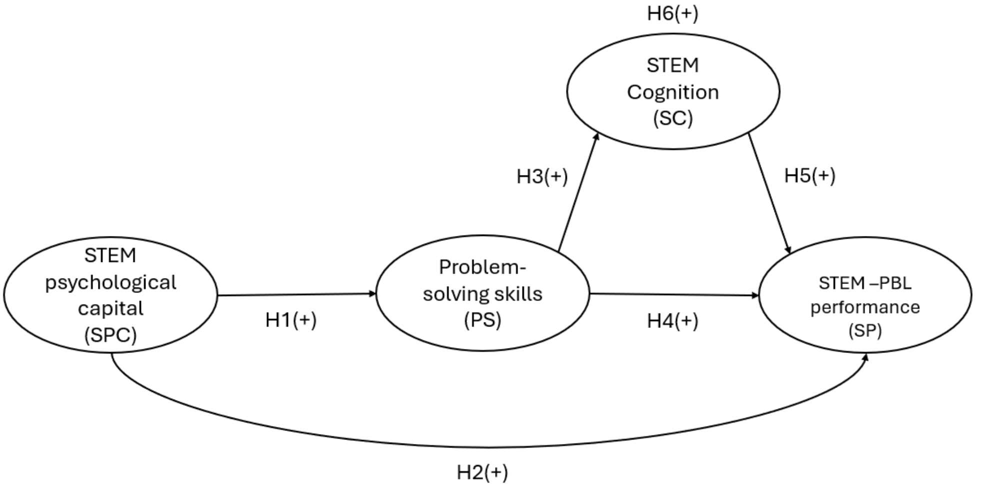
However, the underlying mechanisms of its effectiveness remain underexplored, as do the applications of SPC in PBL. The core constructs of SPC (hope, optimism, and resilience) closely align with the multifaceted learning scenarios of PBL. For example, authentic challenges encountered during PBL can trigger increased motivation and psychological adaptability in learners, thereby supporting improved learning outcomes (Luthans et al., 2004). These psychological traits can act as critical enablers in navigating the complexities and uncertainties inherent in PBL, fostering academic success and also the development of durable skills for interdisciplinary problem-solving.

Research Model and Hypotheses

The literature review discussed above revealed that current CPM applications primarily focus on general cognitive and emotional priming mechanisms, with limited exploration of applications in STEM-specific educational contexts, particularly the role of PC in learning processes. This research gap highlights the need to examine the role of SPC in PBL. Therefore, CPM was integrated with PS and SC to examine their combined influence on learning outcomes. Figure 1 presents the interactions between these constructs and their effects on student performance in STEM-PBL.

- H1: Students' STEM psychological capital (SPC) has a positive effect on their problem-solving skills (PS).
- H2: Students' STEM psychological capital (SPC) has a positive effect on their STEM project-based learning performance (SP).
- H3: Students' problem-solving skills (PS) have a positive effect on their STEM cognition (SC).
- H4: Students' problem-solving skills (PS) have a positive effect on their STEM project-based learning performance (SP).
- H5: Students' STEM cognition (SC) has a positive effect on their STEM project-based learning performance (SP).
- H6: Students' problem-solving skills (PS) have an indirect effect on their STEM project-based learning performance (SP) via STEM cognition (SC).

Figure 1
Research Model



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Research Methodology

General Background

This study utilizes the design and construction of an IoT smart energy-saving house as an educational setting to examine the key factors influencing students' learning processes within the STEM-PBL framework. A quantitative approach was employed, with data collected using a Likert 7-point scale, incorporating the SPC scale, PS scale, and performance assessments comprising SC scores and SP scores. These instruments are designed to comprehensively evaluate students' performance in terms of psychological support, PS, knowledge comprehension, and practical skills, thereby providing empirical evidence from this study on students' STEM learning outcomes.

Participants

This project was conducted from January to May 2021 at a lower-secondary school in Taoyuan City, Taiwan, an institution renowned for its long-standing implementation of interdisciplinary STEM education and high-quality curriculum. The curriculum is distinguished by two notable features: (1) it received an award in a national teaching plan competition, underscoring the excellence of its educational design; and (2) it has been incorporated into textbooks, reflecting its exemplary status in STEM education. Compared to other schools, this curriculum demonstrates a more proficient integration of STEM teaching and learning components, offering a representative sample of students for this study. The IoT smart energy-saving house course was designed for seventh-grade students and spanned 15 weeks. Participation was voluntary, with students informed in advance of their right to withdraw at any time without consequences. To ensure anonymity, participant data were managed using unique identifiers rather than names. After data collection, 26 invalid responses were excluded, yielding a valid response rate of 90%. Missing data were addressed using the median imputation method, resulting in a final sample of 230 students (N = 230), comprising 110 males (48%) and 120 females (52%), as detailed in Table 1.

Table 1
Research Participant Data

Gender	*N*	%
Male	110	48
Female	120	52
Total	230	100

Procedures

An educational model centered on STEM-PBL was constructed. It involved a 15-week period of planned activities that can be divided into two main components, as shown in Table 2.

Table 2
Overview of STEM-PBL Activities

Activity	Course Focus	Course Content	Duration
Cognitive Learning in Technology and Mathematics	Developing foundational knowledge and technical skills.	• Safe operation and use of common hand tools (e.g., soldering irons, coping saws, pliers). • Drawing 3D diagrams with dimensions and annotations. • Understanding machining workflows.	5 weeks: Construction of wooden speakers. 6 weeks: Woodworking and soldering
STEM Project-Based Practical Learning	Applying interdisciplinary knowledge to solve real-world problems.	• IoT concepts and experimental design. • Designing and building IoT smart energy-saving house. • Prototyping, testing, and improving designs iteratively.	4 weeks

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Figure 2-4 presents the practical learning activity. The educational process was guided by the 6E educational model proposed by Burke (2014), with the following phases:

1. Engage:
   Students were introduced to the concept of smart home control systems in everyday life. They explored the key components required to build an IoT system, including devices, sensors, networks, and IoT services.
2. Explore:
   Educational content expanded to include how IoT devices can sense environmental factors around the energy-efficient house, such as temperature and humidity, along with data collection for analysis and control.
3. Explain:
   Teachers facilitated discussions explaining the role of IoT devices in monitoring and managing environmental conditions. Students gained insights into how data collected by IoT sensors can be used to optimize energy efficiency.
4. Engineer:
   Students constructed a comfortable and energy-efficient house, combining theoretical knowledge with practical implementation. During this phase, they applied what they had learned from hands-on activities to integrate IoT concepts into functional designs.
5. Enrich:
   Learning was deepened through activities that encouraged students to control and provide feedback on the functionality of the house. For example, students worked on keeping the environment within the house at an optimal comfort level by monitoring and adjusting devices.
6. Evaluate:
   The evaluation phase employed diverse methods to assess student performance. Open-ended discussion questions were included in the activity worksheets, prompting students to collaborate in groups, search for information online, and synthesize diverse perspectives. The final outputs included organized data, illustrated designs, and presentations.

Figure 2
IoT Smart Energy-Saving House (Front View)

Note. The image illustrates the front design of an IoT smart energy-saving house, showcasing its architectural features, including a balcony, and greenery. Source: https://reurl.cc/A6bM6p.

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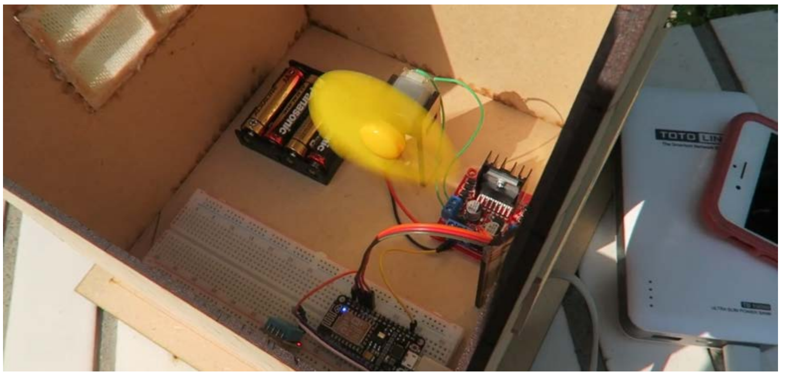
Figure 3
IoT Smart Energy-Saving House (Side View)

Note. The image depicts the external design of an IoT smart energy-saving house, highlighting solar panels and structural features. Source: https://reurl.cc/A6bM6p.

Figure 4
IoT Smart Energy-Saving House (Interior View)



Note. The image shows the internal setup of an IoT smart energy-saving house, featuring electronic components and control systems. Source: https://reurl.cc/A6bM6p.

Instruments

1. The students' SPC scale

This scale was based on the PC framework set out by Luthans and Youssef (2007), which includes four dimensions: hope, optimism, and resilience, with an additional focus on passion and perseverance to be more applicable to the STEM educational model. It was to explore how lower-secondary school students exhibit confidence and sustained effort when faced with complex problem-solving scenarios. Drawing from Duckworth (2009), this scale comprises 10 items (e.g., "I don't give up easily, even when faced with setbacks").

The SPC scale as a measurement tool was administered through a survey method. The SPC scale consists of 22 items, rated on a 7-point Likert scale ranging from 1 ("Not at all like me") to 7 ("Very much like me"). To ensure the content validity of the scale, we invited experts in educational psychology and STEM education to review the

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items. Based on their feedback, we revised the items to improve clarity and relevance (e.g., "When faced with difficulties in learning, I can find various ways to solve the problems" and "I don't give up easily during STEM project activities, even when faced with setbacks") (see Appendix 1). Items with factor loadings below .5 were removed through confirmatory factor analysis.

The validated SPC scale demonstrated reliability and validity, including composite reliability (CR) = .86, average variance extracted (AVE) = .56, and discriminant validity meeting the criteria of AVE square root being greater than the construct's correlations with other constructs (Fornell & Larcker, 1981). The final SPC scale includes 22 items.

2. The students' PS scale

This scale was modified from the problem-solving model proposed by Khunyakari (2015). It measures problem-solving processes and abilities, with higher scores indicating stronger skills. The PS scale was reviewed by experts to improve its validity; the final scale contains 23 items (e.g., "I can analyze the resources and constraints needed to solve a problem") rated on a 7-point Likert scale, ranging from 1 ("Strongly disagree") to 7 ("Strongly agree") (see Appendix 2).

The validated PS scale demonstrated reliability and validity, including (CR = .92), (AVE = .70), and discriminant validity meeting the Fornell and Larcker (1981) criteria.

3. The students' SC scores

Students' SC scores reflect their performance in mathematics and life technology tasks, such as using a coping saw and completing speaker projects. Unlike conventional academic assessments, these tasks emphasize students' ability to integrate interdisciplinary knowledge and apply it to practical problem-solving.

In PBL, students utilize mathematical knowledge in various ways, including data collection, model building, and result analysis. These activities demonstrate their understanding of mathematical concepts and also highlight their ability to apply them to real-world problems. Similarly, real-world challenges demand practical skills and technological applications. For instance, in the coping saw and speaker tasks, students design and construct products that meet specific project requirements. This process requires the integration of material science principles, technical operations, and design thinking, fostering both creativity and problem-solving skills. The validated SC tool demonstrated reliability and validity, with a CR of .79 and an AVE of .66, meeting the criteria for construct reliability (Fornell & Larcker, 1981).

4. The students' SP scores

The STEM project-based activity, themed "IoT Smart Energy-Saving House" aimed to foster students' understanding and application of IoT technologies through the practical implementation of an energy-saving house. The course overview centers on the design and construction of an IoT smart energy-saving house, where students acquire skills in utilizing electronic components, circuit design, and web applications (e.g., ThingSpeak) to integrate technologies for energy conservation. The educational process encompasses comprehending green building metrics, fostering collaboration and innovation, and programming and hands-on implementation, reinforced through group collaboration and empirical data analysis to deepen learning.

The assessment of student performance comprises three key dimensions: First, the knowledge domain evaluates students' grasp of IoT technologies and energy-saving concepts, such as the application of green building metrics. Second, practical competence examines the feasibility and effectiveness of the energy-saving house model, evidenced by data such as humidity levels and fan operation records. Third, the presentation of outcomes assesses students' ability to organize their inquiry process using mind maps and demonstrate creativity. This multifaceted evaluation ensures a comprehensive measure of both theoretical understanding and practical proficiency.

The validated SC scores demonstrated strong reliability and validity, with a CR of .80 and an AVE of .67, meeting the criteria for construct reliability (Fornell & Larcker, 1981).

Data Analysis

Partial Least Squares Structural Equation Modeling (PLS-SEM) (Hair et al., 2017) was employed to assess the associations between latent independent and dependent variables, identifying potential factors influencing STEM

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project performance. This method is considered suitable for the research due to its reduced reliance on normal distribution assumptions, rendering it appropriate for the sample size (Ünal & Uzun, 2021). Based on previous research, the SPC and PS scales were utilized, and a structural equation model (SEM) was applied to validate the hypotheses. All collected data were summarized for analysis, and confirmatory factor analysis was conducted to verify the validity and reliability of the measures.

Research Results

This study aimed to construct an educational model centered on PBL by employing PLS-SEM to assess the reliability and validity of the research model. Following the two-step SEM analysis process, the measurement model was first evaluated for reliability and validity through confirmatory factor analysis, examining items' factor loadings, Cronbach's alpha values, composite reliability (CR) values, and average variance extracted (AVE). Subsequently, the structural model was analyzed to test the hypothesized paths and explanatory power of the variables.

Measurement Model

In PLS-SEM, constructing higher-order models can be approached using either the repeated indicators method or the two-stage approach. Hair et al. (2021) note that the reflective–reflective model is better suited for the repeated indicators method. Because the SPC and PS scales in this study utilized a reflective-reflective model, the repeated indicators method was deemed the more appropriate choice for model construction.

Previous research was built upon (Hair et al. 2021; Wetzel & Wigfield 2009) by establishing first-order constructs. Next, indicators were assigned to corresponding higher-order constructs, and the associated paths were defined. The SPC model includes five constructs: Passion, Perseverance, Hope, Optimism, and Resilience. The final SPC scale consists of 22 items (Table 3), and the PS scale has 23 items, with both scales demonstrating strong reliability and validity (Table 4).

As shown in Table 3, the SPC scale was refined by removing items s1, s18, s19, and s26 due to factor loadings below .5. Next, the scale was reevaluated, and all factor loadings were stable and exceeded .60. The CR value was .86, above the threshold of .6, indicating good internal consistency. The AVE value was .56, higher than the threshold of .5, reflecting strong convergent validity. Furthermore, the square root of AVE values was greater than the inter-construct correlations, confirming discriminant validity.

Table 3
Item Factor Loadings, CR, Cronbach's Alpha Values, and Descriptive Statistics of the SPC Scale

Instrument variables and measurement items			Factor loadings	M (SD)	Cronbach's α	CR	AVE
Second-order constructs	First-order constructs	Item					
SPC	-	-	-	-	.80	.86	.56
	Passion	-	-	-	.70	.81	.52
		s2	.72	3.60 (1.26)			
		s3	.81	5.10 (1.46)			
		s4	.72	4.60 (1.32)			
		s5	.63	5.50 (1.22)			
	Perseverance	-	-	-	.85	.89	.63
		s6	.84	4.70 (1.59)			
		s7	.70	5.00 (1.28)			
		s8	.77	4.80 (1.52)			
		s9	.86	5.00 (1.29)			
		s10	.78	4.80 (1.55)			
	Hope	-	-	-	.87	.90	.60

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Instrument variables and measurement items			Factor loadings	M (SD)	Cronbach's α	CR	AVE
Second-order constructs	First-order constructs	Item					
		s11	.79	4.80 (1.41)			
		s12	.78	5.40 (1.21)			
		s13	.82	5.40 (1.27)			
		s14	.80	5.20 (1.26)			
		s15	.70	5.20 (1.28)			
		s16	.77	4.50 (1.47)			
	Optimism	-	-	-	.84	.89	.68
		s17	.60	4.70 (1.68)			
		s20	.92	4.90 (1.26)			
		s21	.93	5.00 (1.69)			
		s22	.87	4.70 (1.68)			
	Resilience	-	-	-	.81	.89	.73
		s23	.84	4.70 (1.69)			
		s24	.81	5.20 (1.46)			
		s25	.90	4.40 (1.80)			

Note. AVE = Average variance extracted, *CR* = Composite reliability

The measurement model for the PS scale demonstrated reliability and validity after factor analysis, as shown in Table 4. All loadings consistently exceeded .69, indicating strong indicator reliability. The CR values were all above .93, reflecting excellent internal consistency among the constructs. The AVE values were greater than .69, surpassing the recommended threshold of .50, which confirms good convergent validity. Moreover, the square roots of each AVE value were greater than the inter-construct correlations, supporting the discriminant validity of the model. These results confirm that the measurement model possesses adequate reliability and validity.

Table 4
Item Factor Loadings, CR, Cronbach's Alpha Values, and Descriptive Statistics of PS

Instrument variables and measurement items			Factor loadings	M (SD)	Cronbach's α	CR	AVE
Second-order constructs	First-order constructs	Item					
PS	-	-	-	-	.91	.93	.69
	Defining and analyzing				.77	.87	.68
		p1	.82	5.26 (1.15)			
		p2	.81	5.24 (1.17)			
		p3	.85	4.93 (1.14)			
	Collecting and analyzing data	-	-	-	.80	.88	.71
		p4	.84	5.30 (1.18)			
		p5	.85	5.53 (1.20)			
		p6	.83	5.27 (1.14)			
	Developing design ideas	-	-	-	.83	.88	.59
		p7	.74	5.40 (1.34)			
		p8	.80	5.08 (1.32)			
		p9	.74	5.42 (1.33)			
		p10	.80	4.83 (1.25)			
		p11	.77	4.86 (1.16)			

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Planning for making	-	-	-	.74	.84	.56
	p12	.68	4.83 (1.43)			
	p13	.81	5.19 (1.22)			
	p14	.78	5.17 (1.15)			
	p15	.72	5.33 (1.23)			
Making products	-	-	-	.82	.87	.58
	p16	.76	5.70 (1.08)			
	p17	.71	6.28 (0.94)			
	p18	.77	5.78 (1.20)			
	p19	.84	5.93 (1.09)			
	p20	.73	4.93 (1.24)			
Testing, evaluating, and revising solutions	-	-	-	.82	.89	.73
	p21	.83	5.21 (1.25)			
	p22	.91	5.19 (1.27)			
	p23	.83	4.83 (1.32)			

Note. AVE = Average variance extracted, *CR* = Composite reliability

Structural Model

PLS-SEM was employed to examine the associations among SPC, PS, SC, and SP. A collinearity diagnosis was conducted, with variance inflation factor (VIF) values ranging from 1.12 to 3.43, all below the threshold of 5. These findings indicated that collinearity among variables in the structural model was not severe and did not affect the estimation of path coefficients (Hair et al., 2021). To test the hypothesized interactions, a bootstrapping procedure was performed with 5000 random subsamples to evaluate the significance of the hypotheses (Hair et al., 2021). For PLS-SEM, the structural model's quality can be assessed using two key indicators: predictive capability (including path coefficient significance and predictive relevance [Q^2]) and explanatory capability (including explained variance [R^2] and effect size [f^2]).

As shown in Figure 5, the interactions among constructs can be examined through β coefficients, the significance of path coefficients (p-values), and corresponding t-values, which collectively determine the predictive effects between constructs. The predictive ability of each construct was evaluated: the results revealed that path coefficients for Hypothesis 1 (H1), Hypothesis 4 (H4), Hypothesis 5 (H5), and Hypothesis 6 (H6) were significant, supporting these hypotheses. However, Hypothesis 2 (H2) and Hypothesis 3 (H3) were not supported.

1. H1:

SPC predicted PS in lower-secondary school students. The results revealed that SPC had a significant positive predictive effect on PS ($\beta = .72$, $t = 21.42$, $p < .001$). This suggested that higher levels of SPC were associated with stronger PS in lower-secondary school students. Therefore, H1 was supported.

2. H2:

SPC predicted SP in lower-secondary school students. The results showed no significant positive predictive effect of SPC on SP ($\beta = .10$, $t = 1.18$, $p > .05$). Hence, H2 was not supported.

3. H3:

PS predicted SP in lower-secondary school students. The results revealed that PS showed no significant positive predictive effect on SP ($\beta = .09$, $t = 1.08$, $p > .05$). This suggested that higher levels of PS were associated with better SP. Hence, H3 was not supported.

4. H4:

PS predicted SC in lower-secondary school students. The results demonstrated a significant positive predictive effect of PS on SC ($\beta = .15$, $t = 2.42$, $p < .05$). This indicated that stronger PS were associated with higher levels of SC in lower-secondary school students. Therefore, H4 was supported.

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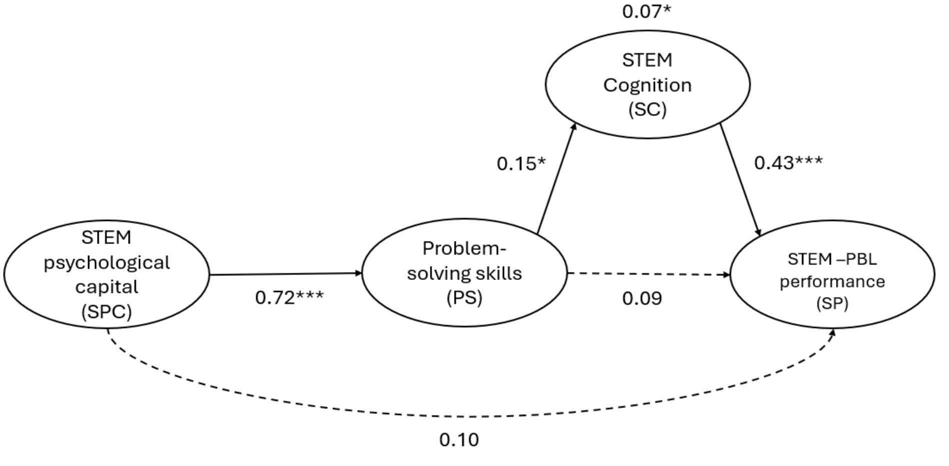
5. H5:

SC predicted SP in lower-secondary school students. The findings revealed a significant positive predictive effect of SC on SP ($\beta = .43$, $t = 7.88$, $p < .001$). This suggested that higher levels of SC were associated with better SP. Hence, H5 was supported.

Figure 5

*Hypothesized Research Model. *p < .05, **p <. 001.*



Following the recommendations of Hair et al. (2021), the predictive relevance of reflective endogenous constructs and their indicators can be assessed using the Stone-Geisser Q^2 value (Geisser, 1974; Stone, 1974). If the Q^2 value exceeds 0, the structural model demonstrates predictive relevance for that construct (Hair et al., 2021). As shown in Table 5, all Q^2 values were greater than 0, indicating the model's predictive relevance. Beyond predictive relevance, the explanatory power of the model was also assessed. The most commonly used indicator for assessing model quality is the coefficient of determination (R^2), which represents the squared correlation between the actual and predicted values of a specific endogenous construct. R^2 measures the extent to which the variance in an endogenous construct is explained by its exogenous predictors. According to Hair et al. (2021), R^2 values close to 0.25 indicate weak explanatory power, values near 0.50 indicate moderate explanatory power, and values approaching 0.70 reflect strong explanatory power.

The R^2 value for the PS construct ($R^2 = 0.52$) indicated moderate explanatory power, the SC construct, with an R^2 value of 0.02, indicated weak explanatory power, and the SP construct ($R^2 = 0.24$) also indicated weak explanatory power. Overall, the conceptual model achieved a moderate level of explanatory capability.

Table 5

Predictive Relevance and Explained Variance

Construct	R^2	Q^2
PS	0.52	0.35
SC	0.02	0.01
SP	0.24	0.14

Note. PS: Problem-solving skills, SC: Cognition, SP: STEM project-based learning performance.

Further analysis of the explanatory effect size (f^2) of each variable provided additional insights, as shown in Table 6. The f^2 value represents the change in R^2 when a specific exogenous variable is removed from the model, indicating its contribution to the explanation of the endogenous variable. According to Cohen's (1988) f^2 guidelines, an effect size is categorized as small when the value falls between 0.02 and 0.15, moderate between 0.15 and 0.35, and large when the value exceeds 0.35.

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The value for the explanatory effect size of SPC was 1.07, signifying a large effect with significant explanatory power. In contrast, the effect sizes of SPC on SP and PS on SP were minimal, suggesting a very limited contribution of these variables to the outcome variable. The effect size of PS on SC was small, while that of SC on SP was moderate, indicating a stronger explanatory contribution.

Regarding model fit, the standardized root mean square residual (SRMR) was examined: for PLS-SEM, an SRMR value between .08 and .10 is considered acceptable (Wang & Wang, 2012). The SRMR for our model was .10, indicating an acceptable level of model fit.

Table 6
Results of Hypothesis Testing

Hypothesis		β	t	f^2	Decision	CILL	CIUL
H1	SPC→PS	.72**	21.12	1.07	Supported	0.65	0.78
H2	SPC→SP	.10	1.18	0.01	Rejected	-0.06	0.27
H3	PS→SC	.09	1.08	0.01	Rejected	-0.08	0.27
H4	PS→SP	.15*	2.42	0.02	Supported	0.03	0.28
H5	SC→SP	.43**	7.88	0.23	Supported	0.32	0.53

Note. SPC: STEM psychological capital; PS: Problem-solving skills; SC: STEM cognition; SP: STEM project-based learning performance; CILL, Confidence interval lower limit; CIUL, Confidence interval upper limit; *$p < .05$, **$p < .001$.

Mediating Role of STEM Cognition

Mediation analysis revealed that SC mediated the interaction between PS and SP with a significant indirect effect, as shown in Table 7. Next, the Variance Accounted For (VAF) was calculated to determine the proportion of the indirect effect relative to the total effect. The VAF value was 44.75%, which falls within the acceptable range of 20% to 80%, indicating partial mediation.

These findings suggested that among lower-secondary school students, PS positively predicted SP partly through SC. These results underscored the critical role of knowledge acquisition in mathematics and technology during STEM project learning processes that emphasize problem-solving. These results supported the assumptions of the CPM, highlighting the facilitative role of SC in linking PS to SP.

Table 7
Mediation Tests

Hypothesis	Independent variable→ dependent variable	Intervening variable	Direct effect	Indirect effect	Total effect	VAF	Decision
H6	PS→SP	SC	0.09 (1.08)	0.07* (2.23)	0.16 (1.62)	44.75%	Supported

Note. PS: Problem-solving skills, SC: STEM cognition, SP: STEM project-based learning performance. *$p < .05$

Discussion

Predictive Effect of SPC on PS and SP

SPC is an innovative construct that includes hope, optimism, resilience, passion, and perseverance. Previous research has confirmed that traditional PC and the concepts of perseverance and passion significantly influence high-order abilities, such as creativity, and have measurable effects on academic performance (Avey et al., 2011; Duckworth et al., 2007; Li et al., 2023; Ortega-Maldonado & Salanova, 2018; Sweetman et al., 2011). Our findings indicate that SPC positively predicts PS, highlighting its critical role in fostering high-order learning capabilities. They support Fredrickson's (2001) broaden-and-build theory, which emphasizes how positive PC enables students to overcome challenges and sustain long-term learning motivation. Students with high levels of PC are better

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equipped to convert positive emotions into the drive to solve problems, thereby enhancing their creativity and sustained engagement.

It is important to note that the predictive role of SPC in SP is not yet fully established, although student PC may indirectly influence academic outcomes (Ortega-Maldonado & Salanova, 2018) and appears to play a mediating role in the association between positive emotions and academic performance (Carmona-Halty et al., 2019). It is noteworthy that, although PC can directly improve actual performance, its effects are mainly realized through indirect paths.

Mediating Role of SC

It was found that SC plays a significant mediating role in the association between PS and SP. PS are typically demonstrated in the processes of analyzing problems, designing solutions, and implementing those solutions, while SC provides the necessary knowledge and skill support throughout these stages. Specifically, SC serves as a bridge for knowledge application, a foundation for practical operations, and a basis for reflection and refinement (Boelt et al., 2022; Stohlmann et al., 2012). It enables students to transform mathematical and technological knowledge into actionable problem-solving strategies.

During the problem-solving process, students must continually test and refine their solutions in practical settings. SC equips students with the skills required to carry out these iterations effectively. Proficiency in technological knowledge, for example, allows students to efficiently complete design and production processes, thereby improving their overall performance. Furthermore, SC supports reflection and iterative improvement. For example, when a design solution deviates from its intended outcome, students can rely on conceptual knowledge to reassess the problem and propose refinement strategies. This reflective process not only enhances the quality of solutions but also enriches understanding of STEM knowledge (Su, 2020).

CPM in STEM-PBL

The results of our study provide empirical support for the design of STEM education and offer novel perspectives on its practical application. Future STEM curricula should emphasize the interaction between PC and cognitive priming mechanisms, fostering supportive learning environments that promote holistic development in knowledge, skills, and attitudes. For example, Fan et al. (2020) emphasized the importance of clearly defining the scope of content knowledge in engineering-based STEM education to provide meaningful learning experiences. Undefined content knowledge could lead to ineffective assessments, ultimately affecting learning outcomes.

Furthermore, Stohlmann et al. (2012) also stressed the importance of integrating and applying knowledge across STEM disciplines while understanding the ability of students to avoid learning pitfalls. Dixon and Brown (2012) noted that inadequate guidance in applying STEM knowledge may hinder cognitive development and interdisciplinary learning among students, particularly if they lack foundational knowledge. Siew and Ahmad (2023) also concluded that insufficient guidance can impair the ability of students to effectively apply knowledge, experiences, and skills during practical tasks, weakening their problem-solving capabilities in STEM activities. These findings reveal several key characteristics of effective STEM instruction: An emphasis on affective development, the integration of multidisciplinary concepts and practices through problem-solving, and clear guidance in connecting relevant STEM knowledge while defining cognitive domains.

Conclusions and Implications

This study explored the interplay of STEM psychological capital (SPC), problem-solving skills (PS), STEM cognition (SC), and STEM project-based learning performance (SP) within a STEM-PBL framework themed on an IoT Smart Energy-Saving Houses. The results demonstrated that SPC significantly enhances PS, which significantly enhances SP through the mediating role of SC, offering a novel insight into psychological and cognitive factors in school STEM education.

These results demonstrate the synergistic interplay between psychological and cognitive factors in supporting lower-secondary school students' ability to apply interdisciplinary knowledge within project-based learning (PBL) contexts. Specifically, SPC fosters passion, perseverance, hope, optimism, and resilience, enabling students to navigate setbacks with confidence and maintain sustained engagement during complex STEM challenges—for

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instance, when designing IoT smart energy-saving houses, students with higher SPC were more likely to persist after initial design failures, adapting their strategies to meet project requirements. Simultaneously, SC enhances students' capacity to integrate mathematical and technological knowledge by facilitating the synthesis of abstract concepts (energy efficiency calculations) with practical applications (programming IoT devices), effectively bridging the gap between theoretical understanding and real-world problem-solving. As a result, students exhibiting elevated levels of SPC and SC demonstrated significantly improved performance in STEM projects, achieving more innovative and functional designs compared to their peers with lower scores. This integrated approach advances our understanding of how psychological and cognitive dimensions interact and also addresses a critical limitation in prior studies that often examined these factors in isolation, overlooking their combined effect on younger learners.

These findings offer implications for STEM education, particularly within the STEM-PBL framework with seventh-grade students in Taiwan. The results suggest that STEM educators should prioritize cultivating SPC by designing supportive learning environments that reinforce passion, perseverance, hope, optimism, and resilience—for example, teachers can implement structured reflection sessions after each design iteration, encouraging students to set small, achievable goals (fostering hope) and celebrate incremental successes (building passion), while providing emotional support to sustain perseverance during challenging prototype testing. Additionally, to enhance SC, educators can develop scaffolded activities, such as teamwork where students first simulate energy consumption scenarios using sensor data and then collaboratively redesign their house models, alongside incorporating peer feedback to refine technical skills. Consequently, this evidence-based, dual-focus approach complements existing STEM curricula by integrating psychological support and cognitive skill development from the outset, offering a practical framework for educators to adapt and implement.

Research Limitations

While our findings provide empirical insights into the psychological and behavioral mechanisms underlying STEM education, certain limitations warrant further exploration. First, the sample consisted of lower-secondary school students from a specific region, and data were collected in a localized STEM teaching context. Although this sampling strategy enhanced internal validity by controlling background variables, differences in teaching strategies, school resources, and educational policies may limit the generalizability of the findings. Specifically, this study focused on seventh-grade students in Taiwan, where cultural and educational factors may have influenced students' psychological capital and problem-solving behaviors. These research findings should be applied cautiously in different educational contexts, and future studies are encouraged to examine whether similar patterns emerge across diverse student populations and schooling environments. Another issue is that, given that the participants were seventh-grade students whose scientific knowledge was still in the early stages of development, the measurement of SC focused on specific performances in mathematics and life technology, emphasizing the application of subject knowledge. While this approach helped delineate the research scope and avoid overly general measurements, it may not fully capture characteristics of other STEM disciplines, such as physics or engineering.

Future Research Recommendations

Future studies may build on our findings to extend and deepen the research design and exploration of variables. For instance, expanding the measurement scope could provide a more comprehensive understanding of SC. Additionally, the interactions among SPC, PS, and SP were examined. While the cross-sectional design was appropriate for preliminary model validation, it does not allow for capturing the long-term developmental effects of SPC. Employing a longitudinal design in future research could provide deeper insights into changes across learning trajectories. Therefore, employing a longitudinal design in future research could track changes in students' PC, PS, and SC across semesters or academic years, verifying causal interactions among variables. Long-term observations could reveal how the cultivation of SPC enhances student comprehension, offering timely guidance for educational strategies. Additionally, future research could explore mechanisms within the integrative model to explore differences in learning processes among diverse student groups, providing empirical evidence for differentiated educational strategies in STEM education. These extensions would not only strengthen the explanatory power of the model but also enhance the practical applicability of the findings, offering theoretical support for the development and practice of STEM education.

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Declaration of Interest

The authors declare no competing interest.

References

Asghar, A., Ellington, R., Rice, E., Johnson, F., & Prime, G. M. (2012). Supporting STEM education in secondary science contexts. *Interdisciplinary Journal of Problem-Based Learning, 6*(2), 85–125. https://doi.org/10.7771/1541-5015.1349

Avey, J. B., Reichard, R., Luthans, F., & Mhatre, K. (2011). Meta-analysis of the impact of positive psychological capital on employee attitudes, behaviors and performance. *Human Resource Development Quarterly, 2*2(2), 127–152. https://doi.org/10.1002/hrdq.20070

Bertieaux, D., Hesbois, M., Goyette, N., & Duroisin, N. (2024). Psychological capital and well-being: An opportunity for teachers' well-being? Scoping review of the scientific literature in psychology and educational sciences. *Acta Psychologica, 24*8, Article 104370. https://doi.org/10.1016/j.actpsy.2024.104370

Blanchette, I., & Richards, A. (2010). The influence of affect on higher level cognition: A review of research on interpretation, judgement, decision making and reasoning. *Cognition & Emotion, 24*(4), 561–595.

Boelt, A. M., Kolmos, A., & Holgaard, J. E. (2022). Literature review of students' perceptions of generic competence development in problem-based learning in engineering education. *European Journal of Engineering Education, 47*(6), 1399–1420. https://doi.org/10.1080/03043797.2022.2074819

Bogg, T., & Finn, P. R. (2010). A self-regulatory model of behavioral disinhibition in late adolescence: Integrating personality traits, externalizing psychopathology, and cognitive capacity. *Journal of Personality, 78*(2), 441–470.

Burke, B. N. (2014). The ITEEA 6E learning by design model: Maximizing informed design and inquiry in the integrative STEM classroom. *Technology and Engineering Teacher, 73*(6), 14–19.

Capraro, R. M., Capraro, M. M., & Morgan, J. R. (2013). *STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) Approach*. Sense publishers.

Carver, C. S., Scheier, M. F., & Segerstrom, S. C. (2010). Optimism. *Clinical Psychology Review, 3*0(7), 879–889.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd edition)*. Erlbaum.

Credé, M., Tynan, M. C., & Harms, P. D. (2017). Much ado about grit: A meta-analytic synthesis of the grit literature. *Journal of Personality and Social Psychology, 113*(3), 492–511. https://doi.org/10.1037/pspp0000102

Carmona-Halty, M., Salanova, M., Llorens, S., & Schaufeli, W. (2019). How psychological capital mediates between study–related positive emotions and academic performance. *Journal of Happiness Studies, 20*(2), 605–617.

Dixon, R. A., & Brown, R. A. (2012). Transfer of learning: Connecting concepts during problem solving. *Journal of Technology Education, 24*(1), 2–16.

Duckworth, A., Peterson, C., Matthews, M., & Kelly, D. (2007). Grit: Perseverance and passion for long-term goals. *Journal of Personality and Social Psychology, 92*(6), 1087-1101. https://doi.org/10.1037/0022-3514.92.6.1087

English, L. D. (2023). Ways of thinking in STEM-based problem solving. *ZDM–Mathematics Education, 55*, 1219–1230. https://doi.org/10.1007/s11858-023-01474-7

Fan, S.-C., Yu, K.-C., & Lin, K.-Y. (2020). A framework for implementing an engineering-focused STEM curriculum. *International Journal of Science and Mathematics Education, 19*, 1523–1541. https://doi.org/10.1007/s10763-020-10129-y

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*(1), 39–50. https://doi.org/10.2307/3151312

Fredrickson, B. L. (2001). The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. *American Psychologist, 56*(3), 218–226.

Geisser, S. (1974). A predictive approach to the random effects model. *Biometrika, 61*(1), 101–107.

Hair, J. F., Jr., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2021). *A primer on partial least squares structural equation modeling (PLS-SEM).* Sage Publications.

Hair, J.F., Sarstedt, M., Ringle, C.M. & Gudergan, S.P. (2017). *Advanced issues in partial least squares structural equation modeling (PLS-SEM)*. Sage Publications.

Khunyakari, R. P. (2015). Experiences of design-and-make interventions with Indian middle school students. *Contemporary Education Dialogue, 12*(2), 139–176.

https://doi.org/10.33225/jbse/25.24.340

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools, 19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Kroll, C., Warchold, A. & Pradhan, P. Sustainable Development Goals (SDGs): Are we successful in turning trade-offs into synergies?. *Palgrave Communications, 5*, Article 140. https://doi.org/10.1057/s41599-019-0335-5

Lamb, R., Akmal, T., & Petrie, K. (2015). Development of a cognition-priming model describing learning in a STEM classroom. *Journal of Research in Science Teaching, 52*(3), 410–437. https://doi.org/10.1002/tea.21200

Lamb, R., Annetta, L., Vallett, D., & Sadler, T. (2014). Cognitive diagnostic like approaches using neural-network analysis of serious educational videogames. *Computers & Education*, *70*, 92–104.

Li, R., Norlizah Che Hassan, & Norzihani Saharuddin. (2023). Psychological capital related to academic outcomes among university students: A systematic literature review. *Psychology Research and Behavior Management, 16*, 3739–3763. https://doi.org/10.2147/prbm.s421549

Lou, S. J., Shih, R. C., Diez, C. R., & Tseng, K. H. (2011). The impact of problem-based learning strategies on STEM knowledge integration and attitudes: An exploratory study among female Taiwanese senior high school students. *International Journal of Technology and Design Education*, *21*(2), 195–215.

Luo, T., Chen, Y., So, W. W. M., & Chiu, S. W. K. (2024). Exploring predictors of STEM aspirations from a STEM capital perspective. *Research in Science & Technological Education*, 1–19. https://doi.org/10.1080/02635143.2024.2320113

Luthans, F., Avolio, B. J., Avey, J. B., & Norman, S. M. (2007). Positive psychological capital: Measurement and relationship with performance and satisfaction. *Personnel Psychology, 60*, 541–572. http://doi.org/10.1111/j.1744-6570.2007.00083.x

Luthans, K. W., Luthans, B. C., & Chaffin, T. D. (2018). Refining grit in academic performance: The mediational role of psychological capital. *Journal of Management Education, 43*(1), 35–61. https://doi.org/10.1177/1052562918804282

Luthans, F., & Youssef, C. M. (2004). Human, social, and now positive psychological capital management: Investing in people for competitive advantage, *Organizational Dynamics, 33*(2), 143–160. https://doi.org/10.1016/j.orgdyn.2004.01.003

Lin, K.-Y., & Lu, S.-C. (2018). Effects of project-based activities in developing high school students' energy literacy. *Journal of Baltic Science Education, 17*(5), 867–877. https://doi.org/10.33225/jbse/18.17.867

Luthans, F., Youssef, C., & Rawski, S. (2011). A tale of two paradigms: The impact of psychological capital and reinforcing feedback on problem solving and innovation. *Journal of Organizational Behavior Management, 31*, 333–350. https://doi.org/10.1080/01608061.2011.619421

Ortega-Maldonado, A., & Salanova, M. (2018). Psychological capital and performance among undergraduate students: The role of meaning-focused coping and satisfaction. *Teaching in Higher Education, 23*(3), 390–402.

Pertiwi, N. P., Saputro, S., Yamtinah, S., & Kamari, A. (2024). Enhancing critical thinking skills through STEM problem-based contextual learning: An integrated e-module education website with virtual experiments. *Journal of Baltic Science Education, 23*(4), 739–766. https://doi.org/10.33225/jbse/24.23.739

Peterson, C. (2000). The future of optimism. *American Psychologist, 55*(1), 44–55. https://doi.org/10.1037/0003-066X.55.1.44

Sweetman, D., Luthans, F., Avey, J., & Luthans, B. (2011). Relationship between positive psychological capital and creative performance. *Canadian Journal of Administrative Sciences, 28*(1), 4–13.

Siew, N. M., & Ahmad, J. (2023). The effects of socioscientific issues approach with thinking wheel maps on entrepreneurial science thinking among fifth graders. *Journal of Baltic Science Education, 22*(1), 100–112. https://doi.org/10.33225/jbse/23.22.100

Su, K.-D. (2020). Enhancing students' high-order cognitive skills for hierarchical designs in micro and symbolic particulate nature of matter. *Journal of Baltic Science Education, 19*(5), 842–857. https://doi.org/10.33225/jbse/20.19.842

Sulaiman, F., Rosales Jr., J. J., & Kyung, L. J. (2023). The effectiveness of the integrated STEM-PBL physics module on students' interest, sense-making and effort. *Journal of Baltic Science Education, 22*(1), 113–129. https://doi.org/10.33225/jbse/23.22.113

Schunk, D. H., & DiBenedetto, M. K. (2020). Motivation and social-cognitive theory. *Contemporary Educational Psychology, 60*, Article 101830. https://doi.org/10.1016/j.cedpsych.2019.101832

Snyder, C. R., Lehman, K. A., Kluck, B., & Monsson, Y. (2006). Hope for rehabilitation and vice versa. *Rehabilitation Psychology, 51*(2), 89–112.

Snyder, C. R., Lopez, S. J., Shorey, H. S., Rand, K. L., & Feldman, D. B. (2002). Hope theory, measurements, and applications to school psychology. *School Psychology Quarterly, 17*(2), 122–139.

Sternberg, R. J. (2003). *Cognitive Psychology (3rd ed.)*. Wadsworth, OH: Thompson Wadsworth.

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research*, *2*(1), 28–34.

Stone, M. (1974). Cross-validatory choice and assessment of statistical predictions. *Journal of the Royal Statistical Society, 36*(2), 111–147.

Suciana, D., Hartinawati, Sausan, I., & Meliza (2023). A meta-analysis study: The effect of problem based learning integrated with STEM on learning outcomes. *European Journal of Education and Pedagogy, 4* (2), 133–138. https://doi.org/10.24018/ejedu.2023.4.2.619

Thomas, J. W., Mergendoller, J. R., & Michaelson, A. (1999). *Project-based learning: A handbook for middle and high school teachers*. Novato, CA: The Buck Institute for Education.

Ünal, E., & Uzun, A. M. (2021). Understanding university students' behavioral intention to use Edmodo through the lens of extended technology acceptance model. *British Journal of Educational Technology, 52*(2), 619–637. https://doi.org/10.1111/bjet.13046

Vallerand, R. J. (2015). *The psychology of passion: A dualistic model*. Oxford University Press.

Wang, J., & Wang, X. (2012). *Structural equation modeling: applications using Mplus*. John Wiley & Sons. https://doi.org/10.1002/9781118356258

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Appendix 1: The students' STEM psychological capital scale

Item
1. During STEM project activities, I do not feel discouraged by setbacks and rarely give up.
2. During STEM project activities, I often set goals but then switch to pursuing different ones.
3. I work diligently during STEM project activities.
4. I find it challenging to stay focused on difficult STEM projects.
5. Once I start working on something during STEM project activities, I won't stop until it's completed.
6. My interests in STEM projects (the topics I want to pursue) frequently change.
7. I am persistent and never give up during STEM project activities.
8. I was once very interested in STEM projects, but I eventually lost interest.
9. I am not afraid of setbacks when overcoming significant challenges during STEM project activities.
10. When I encounter difficulties in learning, I can find various ways to solve the problem.
11. I am currently actively pursuing my goals.
12. I can come up with several ways to achieve the goals I set for myself.
13. At this moment, I am steadily working toward achieving my goals.
14. I consider myself quite successful in learning.
15. There are many solutions to the problems I am currently facing.
16. In moments of uncertainty, I usually anticipate the best outcomes.
17. I always maintain an optimistic attitude toward the future.
18. I always look on the bright side of things.
19. I generally feel that good things are likely to happen.
20. When I face setbacks in life, I can always bounce back and keep moving forward.
21. I don't need much time to overcome stress.
22. I can usually recover quickly from a low point.

Appendix 2: The students' problem-solving skills scale

Item
1. I can identify the key points and priorities of a problem.
2. I can analyze the resources and constraints required to address a problem.
3. I can formulate predictive conditions and directions based on analysis results.
4. I can identify the direction for data collection.
5. I can gather information through various methods and channels.
6. I can analyze and filter accurate and helpful information.
7. I can convey design concepts using images, text, oral descriptions, videos, drawings, or prototypes.
8. I can develop diverse and creative design concepts.
9. I can share design concepts with team members.
10. I can present comprehensive and detailed design concepts.
11. I can use evaluation criteria to objectively judge and select the best concept.
12. I can clearly express specific design plans through text descriptions, sketches, orthographic projections, or models.

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Item
13. I can select appropriate materials and formulate production methods and procedures based on design concepts.
14. I can analyze potential issues and provide necessary assistance in production processes and material handling.
15. I can develop a team-based division of tasks based on a production plan.
16. I can follow designated methods and procedures to execute production tasks.
17. I can adhere to safety regulations during production activities.
18. I can effectively utilize available resources to produce a finished product.
19. I can correctly use materials, tools, and equipment to create a finished product.
20. I can document key problems encountered during production and effectively resolve them.
21. I can test whether the final product effectively solves the intended problem.
22. I can revise and adjust a product based on test results.
23. I can review process records and propose optimal revisions based on evaluation outcomes.

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INTEREST IN STEM AND ITS RELATIONS TO THE EDUCATIONAL ACHIEVEMENT AND SOCIO-DEMOGRAPHIC CHARACTERISTICS OF GRAMMAR SCHOOL STUDENTS IN SERBIA

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Abstract. *Despite the growing prominence of STEM disciplines in contemporary society, relevant studies indicate a concerning trend: a decline in students' interest and engagement in these fields. This research included 1,045 students from four grammar schools in Serbia. The study utilizes a quantitative research design: data were collected through an online questionnaire. Key variables: end-of-term marks in STEM subjects, gender, parental education, family size, and place of residence were analyzed following the answers of respondents. Students were divided into two groups, STEM (435) and Non-STEM (610). The results indicated that the students enrolled in STEM-focused programs demonstrated significantly higher academic performance in STEM subjects during primary education compared to their peers in Non-STEM tracks. Additionally, the study identifies potential relations between students' interest in STEM and factors such as gender, parental education, and place of residence, with no significant effect found for the number of siblings. Specific sample and custom-designed questionnaire, highlight the need for future research with a broader and more diverse sample, incorporating additional socio-demographic factors and qualitative methods for a deeper understanding of students' engagement with STEM fields.*

Keywords: *STEM education, STEM interests, quantitative research, Serbia, grammar school*

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Introduction

STEM (Science, Technology, Engineering, Mathematics) proficiency is increasingly fundamental for informed decision-making, innovation, and active participation in the global economy as society continues to evolve. There is a worldwide consensus that expanding the pool of STEM experts enhances essential resources, promotes health, and maintains well-being (Murphy et al., 2019). From this perspective, STEM education has become central to many educational reforms, as it is vital for developing future work skills (Chiriacescu et al., 2023) and opens greater opportunities in various fields and lucrative careers (Kiernan et al., 2023). Understanding the natural sciences is integral to students' opportunities to create marketable and socially valuable products applicable in fields such as medicine, industry, and ecology (Divac et al., 2022; Nicolaou et al., 2021). Engaging with natural sciences and mathematics fosters essential knowledge and skills for active and responsible participation in modern society, including analytical thinking, critical thinking, and argumentative skills (Pertiwi et al., 2024). Further, it is essential to consistently raise the scope of experts in natural sciences and mathematics, as their shortage poses a risk to the anticipated and desired advancements in social, economic, and technological domains (Avargil et al., 2020).

Researchers analyzing educational trends (John et al., 2022), along with representatives from professional bodies (Committee on STEM Education, National Science & Technology Council, 2018) and international organizations (OECD, 2013), have emphasized the critical need to develop strategies that encourage greater participation of young people in STEM education. The U.S. government has established science as an "area of national need", highlighting that the global potential of the American nation is compromised if more students do not engage in STEM programs (Kanny et al., 2014). However, concerns have arisen regarding the promotion of STEM education across

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many OECD member countries, where students' interest in STEM disciplines has significantly declined over the past 20 years (Clark et al., 2016; Thomson et al., 2017).

Research Problem

Studies indicate that primary and secondary education is a critical period for determining a student's decision to pursue a career in the natural sciences (Sheldrake & Mutjaba, 2020). It is important to examine when students' interest in STEM sciences intensifies or wanes throughout their education and what factors contribute to these changes (Hacieminoglu, 2016; Luo et al., 2021; Ševkušić, 2022; Wakhata et al., 2022). Researchers note that most students begin their education with positive attitudes toward mathematics, but negative attitudes that develop later often result from lower achievements, unsuccessful experiences, and the emotional impact that accompanies failure (Japashov et al., 2022; Song et al., 2021; Vidić & Đuranović, 2020). Students generally recognize the importance of natural sciences in everyday life and find these subjects both interesting and challenging (Nugent et al., 2015): they often perceive these subjects as "not for everyone" (van Tuijl & van der Molen, 2016, p. 172). Research has described students' interest in STEM education as a pipeline, wherein the number of students engaged in these subjects diminishes as they progress through higher grades, a trend that is particularly pronounced among girls (Hacieminoglu, 2016; Luo et al., 2021; Nugent et al., 2015). Studies have explained that STEM interests are changeable and that various aspects, such as family influence, school performance, and the educational context, should be considered. More precisely, the factors can be divided into:

1. Socio-demographic and family background (gender, family size, parental education, place of residence, income and parents' attitude towards mathematics and natural sciences) (Balta et al., 2023; Dönmez, 2023);
2. Student achievements in subjects from natural and mathematical fields, students' attitudes towards these subjects and self-assessment of efficiency in those subjects (John et al., 2022; Ketenci et al, 2020);
3. School infrastructure and educational resources (Wakhata et al., 2022).

The relevant literature indicates significantly minor enrollment of students in grammar schools, especially in STEM-focused departments, in the Republic of Serbia, in contrast to the standard of the developed countries (Ivić, 2023). Furthermore, as far as present researchers know, prior domestic studies have not considered students' grammar school orientations alongside their socio-demographic characteristics (Maksimović et al., 2020). This study, therefore, provides a significant contribution to the current literature by offering a more comprehensive analysis of STEM education. A recent study in Serbia has examined students' perceptions of STEM subjects and grade point average (GPA), revealing that STEM-focused students achieve higher academic performance than their Non-STEM counterparts (Maksimović et al., 2024). Also, those students view STEM subjects as less challenging, more engaging, and more valuable, with biology being an exception.

Despite ongoing efforts to promote STEM education, disparities in student interest persist across different groups. Insufficient understanding of factors contributing to STEM interests hinders the development of effective, targeted interventions. This study considered several factors that impact students' interest in STEM, including gender, family background (such as family size, parental education, and location), and marks in STEM subjects. By understanding these determinants, the study can contribute to the development of more effective strategies and interventions on the national level, ensuring that local educational systems can better support diverse groups of students. Internationally, the findings from this case study can enrich global discussions about STEM education.

Educational System in Serbia

Education in Serbia is organized into four stages: pre-primary, primary, secondary, and tertiary. Children ranging from six months to seven years old are part of the pre-primary program. Primary education is mandatory for children aged 7 and lasts eight years, and is organized into two cycles. In the first cycle, which includes the first four grades, students are taught by a single-class teacher. The second cycle, from grades five to eight, incorporates different school subjects that subject-specific teachers teach. The secondary level comprises four years of education in grammar school (4 grades from age 15 to 19) or three to four years in vocational school (medical, technical, arts, industrial, craft). A grammar school is a type of secondary school that selects students based on academic ability, typically through an entrance examination. This type of school emphasizes a curriculum that aims to provide students with a strong foundation of knowledge for future academic pursuits. At the tertiary level, students can

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continue their education in high schools of applied studies (3 years) or university (Bachelor programs lasting 4–6 years, Master programs lasting 1-2 years and PhD programs lasting 3 years).

Regarding STEM-related subjects in primary school, students have mathematics from the first grade until the end of primary education. During the first four years, they study an integrated science curriculum that combines knowledge from various natural science disciplines. At the same time, children learn about technology and develop digital competencies through different school subjects. In the second cycle in primary school, students in Serbia begin studying physics, chemistry, and biology as separate subjects. Starting in the fifth grade, they also take the subjects of technical education and technology, as well as computer science. Additional support for mathematics and science education in grammar schools in Serbia has been facilitated through the establishment of specialized departments for STEM disciplines.

Students' Marks in STEM Subjects

Previous research has shown that students who achieve high marks in STEM subjects are more inclined toward pursuing careers in STEM fields (Koyunlu Ünlü & Dökme, 2020). High academic achievement and grades in science subjects are recognized as key factors influencing early interest in STEM careers (Lichtenberger & George-Jackson, 2013). A relevant study by Balta et al. (2023) has highlighted several findings: students with high marks in mathematics and chemistry showed significantly greater interest in science, mathematics, and engineering careers; those excelling in biology were more inclined toward science and engineering; and students who performed well in physics exhibited a stronger interest in pursuing STEM-related fields compared to their peers with lower grades.

Japashov et al. (2022) have revealed a strong positive correlation between students' performance in physics and their interest in science and mathematics. The study has also shown that success in mathematics, biology and chemistry was significantly correlated with a strong interest in STEM fields. However, no significant correlation has been found between academic success in any STEM subject and students' career interests in engineering. Other studies have also observed a positive correlation between students' final grades and their interest in STEM careers (Ing, 2014; Koyunlu Ünlü & Dökme, 2020). Moreover, the relation between academic performance and motivation for STEM learning and careers has been supported by research emphasizing the impact of social and motivational factors on STEM achievement (Ketenci et al., 2020; Nugent et al., 2015). These findings suggest that academic achievement plays a role in shaping interest in STEM careers, as students who perform well in STEM-related subjects are more likely to develop a stronger inclination toward these fields.

Gender

Despite the substantial integration of women into the labor market, particularly in developed states, empirical studies demonstrate that gender segregation persists in occupational structures, wage disparities, and educational domains (Codiroli Mcmaster, 2017; Prix & Kilpi-Jakonen, 2022). This phenomenon is especially pronounced in STEM disciplines, which remain heavily male-dominated (Sinnes and Løken, 2014). Furthermore, even in countries widely recognized as pioneers of gender equality, such as those in Northern Europe with long-standing equality policies, younger generations continue to exhibit a preference for traditionally gendered fields of study and career trajectories (Lahelma, 2014; Nylund et al., 2018). The case of Finland presents an illustrative example: despite girls consistently scoring better than boys in science and math tests since 2015, they show significantly less interest in engineering education and careers (Naukkarinen & Bairoh, 2020). Therefore, the influence of gender stereotypes is often pointed out, which determines the professional direction of young people by certain gender expectations, although, based on their achievements, they have had the opportunity to choose differently (Pihl et al., 2018; Saavedra et al., 2014).

The focus of this research is particularly significant to the issue related to the segregation of educational paths of boys and girls already when transitioning from primary to secondary school. The analysis of the career expectations of adolescents regarding gender, as examined in the framework of PISA 2018, has shown differences in educational aspirations between boys and girls. The list of desired occupations indicates that girls prefer positions in the sector of caring for others, such as health or education, while boys see themselves in the areas of protection (army, police), economics and technology (Schleicher, 2019). These findings are important, as occupational values strongly influence students' decisions regarding their fields of study. Boys with conventional values often elect science or mathematics tracks, which are commonly associated with higher prestige and better financial prospects. On the other hand, girls tend to prefer fields that are more socially oriented and centered around interpersonal connec-

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tions (van der Vleuten et al., 2016). In line with this, the results from the PISA 2018 testing show that, on average, only 1% of 15-year-old girls in OECD countries expressed an interest in pursuing ICT-related careers, compared to 8% of boys. On the other hand, in Bulgaria, Estonia, Lithuania, Poland, Serbia, and Ukraine, more than 15% of boys have expressed an interest in pursuing careers in ICT. However, in none of the PISA-participating countries, more than 3% of girls have reported the same. More than one in four boys surveyed by PISA said they expected to work as engineers, scientists, and researchers when they were 30, but less than one in six girls expressed such expectations. Nearly one in three girls with high educational attainment, and only one in eight boys at the same level of attainment, have indicated that they expected to work as health workers (Schleicher, 2019). Such findings indicate that, despite achieving success in mathematics or natural sciences, boys and girls tend to have distinctly different expectations regarding their prospective careers. At the same time, these results are consistent with indicators in earlier PISA cycles when it has been observed that careers in engineering and computing have attracted a relatively small number of girls (OECD, 2013).

Parental Education

The educational level of parents could be an important determinant of their children's educational achievement and future educational pursuits, especially in STEM disciplines (Archer et al., 2012; Ozfidan et al., 2020; Starr et al., 2022). Research consistently shows that students whose parents have had higher education levels, particularly those with degrees in STEM disciplines, are more inclined to choose postsecondary options and succeed in STEM subjects (Šimunović & Babarović, 2020). Parents with a bachelor's degree or STEM-related careers often serve as role models, influencing their children's choices in STEM subjects. Their educational background and professional experiences provide a foundation for comprehending the value of STEM education (Holmes et al., 2017). Parental expectations significantly impact students' aspirations in STEM (Lissitsa & Chachashvili-Bolotin, 2021). When parents encourage school achievement and express positive beliefs about STEM fields, students are more likely to develop an interest in these subjects (Hsieh & Yu, 2022). Educated parents tend to engage more actively in their children's education, which can enhance their learning experiences. This involvement includes providing resources, guidance, and encouragement related to STEM, fostering an encouraging environment for academic success (Šimunović et al., 2018). The support and resources provided by educated parents, creating a stimulating home environment using games and educational material, can lead to better school performance (Feser, 2024; Perera, 2014; Siregar et al., 2023). While many studies emphasize the positive influence of parental education, some research suggests that its impact is not uniform across all students (Chachashvili-Bolotin et al., 2016). Factors such as socioeconomic status, cultural background, and individual students' circumstances can mediate the effects of parental education on STEM choices (Šimunović et al., 2018).

Number of Siblings

The concept of resource dilution suggests that larger families may face constraints in terms of parental time, attention, and financial resources, which can negatively impact educational attainment (de Haan, 2010). The parents' influence remains important in shaping children's educational paths, but siblings can also contribute in fostering interest in STEM fields. Siblings often learn from each other, with older siblings serving as role models. This dynamic can shape younger siblings' attitudes toward education, including their interest in STEM subjects (Gabay-Egozi et al., 2022). For example, if an older sibling excels in math or science, it may inspire younger siblings to pursue similar paths (Chakraverty et al., 2018). In smaller families, older brothers and sisters often have greater access to these resources, which can enhance their school achievements and, by extension, influence their younger siblings (Ho et al., 2020). Older siblings' academic success, particularly in subjects like math, can significantly shape younger siblings' interests and motivations. Research has indicated that younger siblings may experience increased motivation or anxiety about STEM fields based on their older siblings' performance and attitudes toward these subjects (Antonijević & Radenović, 2024; Legewie & DiPrete, 2014). The composition of the sibling group, such as the number of siblings and their genders, can also influence the formation of STEM-related interests. For instance, a family with multiple siblings in STEM fields may create an environment that emphasizes the importance of these subjects, leading to higher collective interest and achievement (Shahbazian, 2021).

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Place of Residence

The difficulties encountered by rural students, particularly in STEM education, highlight significant disparities between rural and urban/suburban educational experiences. Geographic isolation, limited funding, and a shortage of qualified teachers are critical barriers that contribute to lower educational aspirations and achievements in these areas (Murphy, 2023; Siew et al., 2016). Rural schools often struggle to recruit and retain highly qualified STEM educators, leading to a reliance on teachers with multiple subject endorsements (Gándara et al., 2001). This can dilute the quality of teaching and limit students' exposure to advanced coursework. Additionally, community attitudes toward postsecondary education can further discourage students from pursuing STEM fields, especially when role models are scarce. The tension that rural youth experience – balancing the desire for educational and vocational opportunities with the pull of their home communities – adds another layer of complexity. Many students may feel pressured to stay close to family, which can hinder their pursuit of advanced education in STEM (Meece et al., 2013). Without access to quality educational materials and training, students face barriers in preparing for careers in STEM fields. This cycle of underachievement in STEM can have long-term effects on both individual students and the broader rural community (Peterson et al., 2015).

Research Aim and Research Questions

Along the lines of researchers who believe that education can catalyze social changes and the development of both individuals and the state, this study deals with certain aspects of education in STEM disciplines. The present research specifically examined grammar school students' prior academic experiences, to identify relations with students' interests in STEM, comparing the responses of students in STEM-focused departments with those in other tracks. Therefore, the aim of this study was to examine the relations of some socio-demographic characteristics as well as school achievement on students' STEM interests. In alignment with the aim of the research, the following research questions have been formulated:

1. Are end-of-term marks in STEM subjects related to students' interest in STEM fields?
2. Is gender related to students' interest in STEM fields?
3. Is parental education related to students' interest in STEM fields?
4. Is the number of siblings related to students' interest in STEM fields?
5. Is the place of residence related to students' interest in STEM fields?

Research Methodology

General Background

This research was carried out between October 2023 and July 2024 using a quantitative research design. The study included grammar school students from the Republic of Serbia, encompassing both, specialized departments and regular departments, allowing for a comparative analysis of the factors influencing students' choices across different types of academic tracks. The theoretical framework of the research focused on the socio-demographic and individual factors that could shape students' academic trajectories. The students were surveyed about their previous educational experience and socio-cultural characteristics to identify predictors of enrollment in specialized (STEM) departments in grammar school.

Sample

A sampling procedure was utilized due to its effectiveness and ability to access a large, geographically distributed student population (Lefever et al., 2006). The sample encompassed 1045 grammar school students, both male (330) and female (715). These students were from four grammar schools in two cities in the Republic of Serbia, two in Kragujevac (551) and two in Novi Sad (494). The four schools adhered to the national educational framework set by the Ministry of Education of the Republic of Serbia. (Law on the Foundations of the Education System in the Republic of Serbia, 2024). In order to answer research questions, the students were classified into two groups, STEM (435) and Non-STEM (610) according to the methodology presented by Weeden et al. (2020), adapted to the educational context in Serbia. The distribution of sample students across two groups, along with their respective departments, is presented in Table 1.

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Table 1
Distribution of Students Within Sample Across Grammar School Departments

Group	Department	*n*
STEM	Natural sciences and mathematics department	222
	Specialized department for mathematics	63
	Specialized department for computer science	84
	Specialized department for physics	11
	Specialized department for biology and chemistry	55
Non-STEM	General stream of studies	464
	Socio-linguistic department	48
	Bilingual department	55
	Specialized department for sports	14
	Specialized department for philology	29
Total		1045

Ethics

All students took part in the research on a voluntary basis and were approached in line with the highest ethical principles upheld in educational research. Prior to gathering empirical data, a comprehensive form was prepared outlining all relevant details, including the study's purpose, procedures, and requirements. The research adhered to applicable laws and institutional regulations and received ethical approval from the Ethics Committee of the Faculty of Science, University of Kragujevac (No. 01-06/24).

Instrument and Procedures

Data were collected using an online questionnaire (see Appendix) administered via Google Forms. The questionnaire was designed to gather information on students' socio-demographic background, family characteristics, and academic performance, including gender, number of siblings, parental education, place of residence, and end-of-term marks in STEM subjects. The study aimed to examine potential relations between socio-demographic factors and educational achievements and students' enrollment in specialized STEM departments. Given the focus on identifying patterns and associations rather than assessing subjective attitudes or perceptions, the questionnaire was designed to include only key background characteristics that have been recognized in previous research as influential in educational decision-making. The instrument was created by adopting some of the questions from different questionnaires (Hoffmeyer-Zlotnik & Warner, 2007; Japashov, et al., 2022). Two independent experts checked the validity of the questionnaire content.

Data Analysis

Statistical measures and procedures included: frequencies, percentages, arithmetic means, and standard deviations, as well as a statistical test for determining the normality of data distribution (the Kolmogorov-Smirnov test), followed by the Mann-Whitney test and the Chi-square test. The collected data were processed using the IBM SPSS Statistics 20 software package.

Research Results

Interest in STEM and Students' End-of-Term Marks in STEM Subjects

Marks in the Serbian educational system are numerical and on a scale from 1 (insufficient) to 5 (excellent) (Law on Education System Foundations in the Republic of Serbia, 2024). The arithmetic mean is considered during

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evaluation; for example, students who have an average grade between 3.5 and 4.5 have very good success (grade 4), or higher than 4.5 have excellent success (grade five) in that subject. To address the first research question, it was examined whether the achievements in the STEM subjects during primary education differ between the two groups. Bearing in mind that the distribution of students' end-of-term marks did not follow the normal distribution, potential differences among the three groups were examined using the appropriate Mann-Whitney test.

Table 2
End-of-Term Marks in STEM Subjects Between STEM and Non-STEM Students During

Subject	Group	*M*	*SD*	Mann-Whitney U test	
				Z	*p*
Biology	STEM	4.86	0.50	-3.143	.002
	Non-STEM	4.76	0.59		
Physics	STEM	4.78	0.61	-7.557	<.001
	Non-STEM	4.44	0.85		
Chemistry	STEM	4.76	0.66	-6.472	<.001
	Non-STEM	4.38	0.84		
Mathematics	STEM	4.77	0.61	-7.965	<.001
	Non-STEM	4.38	0.92		
Computer Science	STEM	4.94	0.40	-3.624	<.001
	Non-STEM	4.87	0.42		
Technical education and technology	STEM	4.90	0.49	-0.636	.525
	Non-STEM	4.91	0.39		

According to Table 2, it is evident that the students from the STEM group were excellent in all six subjects. On the other hand, the Non-STEM students were excellent in three subjects (technical education and technology, computer science and biology), whilst they were very good in the other three (physics, chemistry and mathematics). The differences between the two groups are statistically significant in 5 out of 6 subjects (biology, physics, chemistry, mathematics and computer science). Statistical indicators (Table 2) indicate that students from STEM departments achieved significantly better results in STEM subjects during primary school education.

Interest in STEM and Gender

Furthermore, there was an examination of gender representation between the two groups. The distribution of students by gender in the STEM and Non-STEM departments is presented in Table 3.

Table 3
Gender Distribution of Students in STEM and Non-STEM Groups

Group	*n*	
	Gender	
	Male	Female
STEM	196	239
Non-STEM	134	476
Total	330	715

Based on the results gathered, nearly 60% of the boys were directed toward studying STEM, while only one in three girls from the sample (33.43%) chose to pursue STEM education in more detail. These differences are statisti-

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cally significant ($\chi^2 = 61.59$; $df = 1$; $p < .001$). Therefore, according to the research sample, it can be concluded that boys decide to study STEM departments to a significantly greater extent than girls.

Interest in STEM and Parental Education

Summarized data about mothers' education of students among both groups are presented in Table 4. To meet the assumption of the chi-square test regarding the least cell frequency, 5 responses from mothers who completed only primary school will be joined to the number of mothers who have completed high school. Results from Table 4 reveal an almost similar number of mothers with a bachelor's degree, whilst the number of mothers with a master's degree is significantly higher among STEM group students (65.98% of mothers of STEM students and 52.46% of mothers of Non-STEM students). Observed differences are statistically significant ($\chi^2 = 24.15$; $df = 2$; $p < .001$).

Table 4
Distribution of STEM and Non-STEM Students by Mother's Education Level

Group	*n*			
	Mother's Education Level			
	Elementary Education	Secondary Education	Bachelor's Degree	Master's Degree
STEM	1	88	59	287
Non-STEM	4	202	84	320
Total	5	290	143	607

Table 5 presents the data regarding fathers' educational level. Similar to the data gathered about mothers' education, the number of fathers with a higher level of education is noticeably greater among students from STEM departments. Based on the results of the chi-square test ($\chi^2 = 10.73$; $df = 2$; $p = .013$), it turns out that the differences in the education of the fathers of the two groups of students are also statistically significant.

Table 5
Distribution of STEM and Non-STEM Students by Father's Education Level

Group	*n*			
	Father's Education Level			
	Elementary Education	Secondary Education	Bachelor's Degree	Master's Degree
STEM	4	143	47	241
Non-STEM	13	247	69	281
Total	17	390	116	522

Interest in STEM and Number of Siblings

Since family size could impact students' choice of STEM education, it was investigated whether the size of the family, specifically the number of siblings, differs among the two groups in the research sample. Values from Table 6 show that the majority of students have one sibling (59.31% of students from the STEM group and 55.57% of students from the Non-STEM group). Based on the chi-square test, the STEM interests and the number of siblings are independent variables ($\chi^2 = 8.82$; $df = 4$; $p = .266$). In other words, there are no statistically significant differences in the number of siblings among the two groups of students.

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Table 6
Distribution of STEM and Non-STEM Students by Number of Siblings

Group	*n*				
	Number of Children in Family				
	Single child	Two children	Three children	Four children	Five or more children
STEM	83	258	76	9	9
Non-STEM	103	339	132	21	15
Total	186	597	208	30	24

Interest in STEM and Place of Residence

Bearing in mind the possible influence of students' place of residence on STEM interest, there were examined differences in the allocation of students in STEM and Non-STEM departments depending on whether they live in urban or rural localities. In general, a small number of students grew up in rural places (16% of STEM students and 27% of Non-STEM students), compared to the number of students who grew up in urban environments (84% of STEM students and 73% of Non-STEM students). Differences in distribution (Table 7) are easily noticeable, and they are statistically significant ($\chi^2 = 15.65$; $df = 1$; $p < .001$). It can be concluded that STEM-oriented students grew up in larger and more urban areas.

Table 7
Distribution of STEM and Non-STEM Students by Place of Residence

Group	*n*	
	Place of Residence	
	Rural locality	Urban locality
STEM	71	364
Non-STEM	164	446
Total	235	810

Discussion

The present study reveals that students' interest in STEM varies based on factors such as gender, place of residence, parental education, and end-of-term marks in STEM subjects. However, no significant differences were observed concerning family size, particularly the number of siblings.

In a similar vein, Jiang et al. (2020) argued that STEM intentions can be viewed as the outcome of motivational factors and learning experiences, which are linked to high school seniors' math performance, exposure to math and science courses, and their confidence in their proficiency in solving math problems. According to Chachashvili-Bolotin et al. (2016) math achievements as well as involvement in extra-curricular STEM activities and advanced science courses are strongly associated with higher students' aspirations toward STEM. Kaleva et al. (2019) found that 16-year-old students who chose to learn advanced mathematics had received good marks in mathematics during their previous schooling. A strong sense of STEM identity could be linked to better educational outcomes and success in undergraduate physics courses, especially for female students (Seyranian et al., 2018). In line with this, the link between mathematics and natural sciences achievements and interest is highlighted by the findings of a study conducted by Laine et al. (2020), which examined marks and interest in STEM among Finnish students aged 12–14. The study revealed that, initially, students' interest predicts their marks, but later, their marks become

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predictors of their interest (Laine et al., 2020). Therefore, it can be concluded that students with higher marks in STEM subjects during their education demonstrate greater interest in continuing to learn STEM disciplines.

The results obtained in this research indicate that boys in the Republic of Serbia are more predisposed than girls to study STEM fields. The findings align with the literature on this global phenomenon (European Commission, 2020; National Science Board, 2022). Comparable research conducted in the Netherlands, which included 1062 adolescents, also showed that 38% of those enrolled in the science and technology track were girls (van der Vleuten et al., 2016). Just like previous research in Serbia (Hrnčić et al., 2014; Ševkušić, 2022) and national statistical data (Statistical Office of the Republic of Serbia, 2022), this research also showed gender gap related to the choice of the STEM area. On the other hand, the findings of a recent international study including a significant sample of 11,782 students from different countries are compelling: students from Serbia and Estonia demonstrate the strongest "mathematical identity" (Radišić et al., 2024). Notably, only in the groups from Serbia and Sweden, there were no significant differences between boys and girls regarding their perception of this identity (Radišić et al., 2024). This highlights the importance of fostering a strong mathematical identity in every student, regardless of gender, to promote a more inclusive and effective learning environment.

The role of parental education in shaping students' career choices, particularly in STEM fields, has been widely studied, with many researchers emphasizing its significance. This study showed significant differences in students' STEM interests based on either fathers' or mothers' education levels. Specifically, students whose parents had higher education levels exhibited greater interest in STEM disciplines compared to those with lower parental education levels. These findings align with previous research which highlights the positive impact of parental education on sustained interest and success in STEM disciplines (Dönmez et al., 2022). Numerous studies have highlighted that families with greater educational attainment tend to be more successful in encouraging students' inclination in STEM (Liu et al., 2022; Svoboda et al., 2016). The parents' influence on some aspects of education was observed in a TIMSS 2015 study in Serbia and showed that better educational achievements are performed by pupils whose parents have a higher level of education (Gundogan et al., 2020). On the other hand, no significant differences have been established in terms of interest in STEM subjects among students, regardless of whether considering fathers' or mothers' education levels, in studies conducted in different countries (Jodl et al., 2001; Koyunlu Ünlü & Dökme, 2020; Lichtenberger & George-Jackson, 2013; Saleem et al., 2014). Although the difference is not statistically significant, Chachashvili-Bolotin et al. (2016) noted that students with parents who have less formal education tend to show less interest in STEM subjects than their peers. Some researchers imply that relatives' appreciation of STEM trajectories and parents' active involvement in promoting STEM have a stronger influence on youth career aspirations than parental education or socioeconomic status (Lichtenberger & George-Jackson, 2013; Nugent et al., 2015).

Early research dealt with the effects of family size on education: a negative correlation between family size and educational outcomes has been noted, which was attributed to limited financial and parental resources in larger families (Downey, 1995). Researchers from Kazakhstan revealed the same correlation between family size, in terms of sibling count, and students' enthusiasm for mathematics (Balta et al., 2022). Furthermore, one Swedish study has shown that students from larger families choose STEM only if an older sibling has previously attended or is currently enrolled in a STEM program (Shahbazian, 2021). However, the present study found no significant differences in STEM career interest based on family size, more specifically, the number of siblings. These findings align with results from Pakistan, which also found no significant differences in educational outcomes based on family size (Ali et al., 2017). Furthermore, while previous research highlights that siblings may influence educational choices and interests (Shahbazian, 2021), data from this research suggests that the number of siblings does not significantly impact STEM interests. Reports from other researchers (Japashov et al., 2022) are consistent with the results obtained in this study and suggest that other factors, such as the quality of sibling relationships may have a more significant impact than merely the number of siblings alone.

Relevant sources reported that mathematics and science achievements and interests did not vary notably among students from different geographical areas in national evaluations (Showalter et al., 2017). However, the present research suggests that disparities in STEM interests are becoming more apparent, possibly due to growing regional inequities and evolving educational landscapes in Serbia. Obtained findings that STEM-oriented students predominantly live in urban areas align with prior research highlighting the disparity in STEM participation and performance between rural and metropolitan students (Nissinen et al., 2018; Thomson et al., 2019). Global trends have revealed similar patterns, where rural students exhibit reduced participation in advanced mathematics, chemistry, and physics courses (Dönmez et al., 2022; Murphy, 2023) and typically demonstrate lower academic ambitions (Fray et al., 2020). Moreover, rural students are less inclined to view science as relevant to their future professional endeavors (Murphy, 2023). However, unlike the findings in the studies mentioned above, research from Kazakhstan,

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Turkey, and Israel revealed that rural students showed more interest in STEM subjects compared to those from urban areas (Chachashvili et al. 2016; Japashov et al., 2022; Koyunlu Ünlü & Dökme, 2020). Furthermore, they explained that rural students perceive STEM careers as a pathway to economic improvement, fostering greater intrinsic motivation. Several factors identified in the sources explain the underrepresentation of STEM-oriented students from rural areas. Rural students often lack access to advanced mathematics and science subjects, as well as extracurricular STEM activities, which are known to nurture interest in STEM careers (Franz-Odendaal et al., 2016, Peterson et al., 2015; Siew et al., 2016). Rural environments may impact children with lower expectations for educational attainment and less exposure to STEM professionals, further reducing STEM aspirations (Kilpatrick & Fraser, 2018; Munn et al., 2018).

Research by Ketenci et al. (2020) indicates that students who tend to pursue STEM-related careers are predominantly male, enrolled in non-public schools with a high socio-economic background, and exhibit strong confidence in their mathematical abilities. It is noteworthy to recognize that the advancement of STEM depends on the inclusion of all qualified and capable students (Charlesworth & Banaji, 2019). Furthermore, progress in achieving equality, particularly in the education of girls, students from disadvantaged families and those from rural areas can significantly contribute to economic growth. Enhancing student achievement and helping individuals reach their full potential through education, while effectively promoting and implementing inclusivity, equality, and fairness in school systems, are not just ideals to strive for; they are essential goals. Attaining these objectives can significantly improve the well-being of both society and individuals: a more educated population leads to increased productivity, which in turn fosters higher economic growth and reduces poverty (Maksimović, 2023; Schleicher & Zoido, 2016).

Conclusions and Implications

According to the available sources, it appears that STEM professionals (will) play a crucial role in shaping various aspects of science, economy and society in the future. Despite this critical need, the number of students pursuing STEM subjects remains insufficient globally and in Serbia as well. Given that no comprehensive studies have been conducted in Serbia or neighboring regions to explore the relations between students' interest in STEM subjects, their educational achievements in these disciplines, and their socio-demographic characteristics, this research aims to contribute to understanding these connections.

The study highlights the significant relation of early academic success on students' interest in STEM fields. Students who engage more intensively in STEM subjects during grammar school demonstrated considerably higher academic achievement in subjects like biology, physics, chemistry, mathematics, and computer science during their primary education. This underscores the importance of fostering early interest and confidence in STEM disciplines. Moreover, interest in STEM is found to be significantly associated with gender, parental education, and place of residence, whereas the number of siblings does not appear to influence STEM motivation. The typical student gravitating toward STEM education in Serbia is male, comes from a highly educated family, and resides in an urban area. These findings point to disparities in access to STEM opportunities that are linked to socio-cultural and environmental factors. Gender imbalances, in particular, suggest a need for targeted interventions to engage female students and address existing biases. Furthermore, rural students face significant challenges in accessing STEM education, indicating a clear need for targeted interventions to ensure equitable opportunities for all, regardless of geographic location. While the number of siblings was not found to significantly influence STEM interest, this suggests that family size, in isolation, is not a critical determinant.

The insights derived from these results are relevant for educators, career advisors, and policymakers involved in guiding students' academic choices, particularly during the transition from primary to secondary education. By understanding the complex socio-demographic factors shaping students' STEM interests, targeted strategies can be developed to support all students, including those who do not fit the typical STEM profile but demonstrate potential. It is important to offer all students, regardless of their socio-demographic characteristics, out-of-school learning experiences that nurture STEM motivation, such as visits to science centers, research laboratories, and industrial institutions. These activities can provide students with immersive experiences that reinforce their interest in STEM fields. This research contributes to the global dialogue on STEM inclusion, advocating for educational systems that are accessible, equitable, and supportive of all students, regardless of gender, socio-economic background, or geographic location. Finally, the study lays the foundation for future longitudinal research that tracks changes in STEM interest over time, offering valuable insights into the effectiveness of educational policies and interventions aimed at increasing STEM participation globally.

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Limitations and Recommendations

The research has certain inherent limitations. The design and implementation of this research were carried out with an understanding of the limited generalizability of the findings beyond the specific context in which they were gathered. The dominant limitation stems from the chosen research approach and data collection method. Considering that the study was limited to four grammar schools in Serbia, it is suggested that subsequent research include a larger and more diverse sample. Moreover, the questionnaire was custom-designed for this research and focused solely on exploring potential relations between students' STEM interests and specific educational and socio-demographic variables. Consequently, the scope of the instrument is limited in its broader applicability. Further research, based on this topic, could also include other family-related factors, such as socio-economic status and parental involvement, which may play an important role in shaping students' engagement with STEM fields. Additionally, while this study employed a quantitative approach, integrating qualitative methods could provide a more thorough comprehension of the factors influencing students' interest in STEM education and careers.

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Declaration of Interest

The authors declare no competing interest.

References

Ali, A., Ahsan, S., & Dziegielewski, S. F. (2017). Social and family capital and youth career intension: A case study in Pakistan. *Cogent Business & Management*, *4*(1), Article 1362838. https://doi.org/10.1080/23311975.2017.1362838

Antonijević, R., & Radenović, D. (2024). Školski uspeh učenika i obrazovni nivo roditelja u kontekstu porodične sredine [Student academic performance and parents' educational level in the context of the family environment], *Teaching Innovations*, *37*(3), 59–74. https://doi.org/10.5937/inovacije2403059A

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal*, *49*(5), 881–908. https://doi.org/10.3102/0002831211433290

Avargil, S., Kohen, Z., & Dori, Y. J. (2020). Trends and perceptions of choosing chemistry as a major and a career. *Chemistry Education Research and Practice, 21*, 668–684. https://doi.org/10.1039/c9rp00158a

Balta, N., Japashov, N., Mansurova, A., Tzafilkou, K., Oliveira, A. W., & Lathrop, R. (2022). Middle- and secondary-school students' STEM career interest and its relationship to gender, grades, and family size in Kazakhstan. *Science Education*, *107*(2), 401–426. https://doi.org/10.1002/sce.21776

Balta, N., Japashov, N., Karimova, A., Agaidarova, S., Abisheva, S., & Potvin, P. (2023). Middle and high school girls' attitude to science, technology, engineering, and mathematics career interest across grade levels and school types. *Frontiers in Education*, *8*, Article 1158041. https://doi.org/10.3389/feduc.2023.1158041

Chachashvili-Bolotin, S., Milner-Bolotin, M., & Lissitsa, S. (2016). Examination of factors predicting secondary students' interest in tertiary STEM education. *International Journal of Science Education*, *38*(3), 366–390. https://doi.org/10.1080/09500693.2016.1143137

Chakraverty, D., Newcomer, S. N., Puzio, K., & Tai, R. H. (2018). It runs in the family: The role of family and extended social networks in developing early science interest. *Bulletin of Science, Technology and Society*, *38*(3–4), 27–38. https://doi.org/10.1177/0270467620911589

Charlesworth, T. E. S., & Banaji, M. R. (2019). Gender in science, technology, engineering, and mathematics: Issues, causes, solutions. *Journal of Neuroscience*, *39*(37), 7228–7243. https://doi.org/10.1523/JNEUROSCI.0475-18.2019

Chiriacescu, F. S., Chiriacescu, B., Grecu, A. E., Miron, C., Panisoara, I. O., & Lazar, I. M. (2023). Secondary teachers' competencies and attitude: A mediated multigroup model based on usefulness and enjoyment to examine the differences between key dimensions of STEM teaching practice. *PLoS ONE*, *18,* Article 0279986. https://doi.org/10.1371/journal.pone.0279986

Clark, E. K., Fuesting, M. A., & Diekman, A. B. (2016). Enhancing interest in science: Exemplars as cues to communal affordances of science. *Journal of Applied Social Psychology*, *46*, 641–654. https://doi.org/10.1111/jasp.12392

Codiroli Mcmaster, N. (2017). Who studies STEM subjects at A level and degree in England? An investigation into the intersections between students' family background, gender and ethnicity in determining choice. *British Educational Research Journal*, *43*(3), 528–553. https://doi.org/10.1002/berj.3270

Committee on STEM Education, National Science & Technology Council. (2018). *Charting a course for success: America's strategy for STEM education*. https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

De Haan, M. (2010). Birth order, family size and educational attainment. *Economics of Education Review*, *29*(4), 576–588. https://doi.org/10.1016/j.econedurev.2009.10.012

Divac, V., Stašević, F., Kostić, M., Popović, D., & Đurđević Nikolić, J. (2022). Inquiry and project-based learning as an approach for developing entrepreneurship competencies in primary school high-achieving students. *Journal of Baltic Science Education*, *21*(6A), 1143–1163. https://doi.org/10.33225/jbse/22.21.1143

Dönmez, I., Idin, S., Gürbüz, S. (2021). Determining lower-secondary students' STEM motivation: a profile from Turkey. *Journal of Baltic Science Education*, *21*(1), 38–51. https://doi.org/10.33225/jbse/22.21.38

Dönmez, İ. (2023). Breaking gender stereotypes: How interacting with STEM professionals changed female students' perceptions. *Journal of Baltic Science Education*, *22*(6), 974–990. https://doi.org/10.33225/jbse/23.22.974

Downey, D. B. (1995). When bigger is not better: Family size, parental resources, and children's educational performance. *American Sociological Review*, *60*(5), 746–761. https://doi.org/10.2307/2096320

European Commission (2020). *Women in Digital Scoreboard 2020*. https://digital-strategy.ec.europa.eu/en/library/women-digital-scoreboard-2020

Feser, M. S. (2024). Parents' views on the use of AI-based chatbots such as ChatGPT in high school (STEM) education. *Journal of Baltic Science Education*, *23*(1), 4–8. https://doi.org/10.33225/jbse/24.23.04

Franz-Odendaal, T. A., Blotnicky, K., French, F., & Joy, P. (2016). Experiences and perceptions of STEM subjects, careers, and engagement in STEM activities among middle school students in the maritime provinces. *Canadian Journal of Science, Mathematics, and Technology Education*, *16*, 153–168. https://doi.org/10.1080/14926156.2016.1166291

Fray, L., Gore, J., Harris, J., & North, B. (2020). Key influences on aspirations for higher education of Australian school students in regional and remote locations: A scoping review of empirical research, 1991–2016. *The Australian Educational Researcher*, *47*(1), 61–93. https://doi.org/10.1007/s13384-019-00332-4

Gabay-Egozi, L., Shavit, Y., & Yaish, M. (2015). Gender differences in fields of study: The role of significant others and rational choice motivations. *European Sociological Review*, *31*(3), 284–297. https://doi.org/10.1093/esr/jcu090

Gándara, P., Gutiáez, D., & O'Hara, S. (2001). Planning for the future in rural and urban high schools. *Journal of Education for Students Placed at Risk (JESPAR)*, *6*(1–2), 73–93. https://doi.org/10.1207/S15327671ESPR0601-2_5

Gundogan, D., Malinić, D. & Radulović, M. (2020). Mogu li različiti načini rada u nastavi da utiču na povezanost društvenog položaja i postignuća učenika? [Can different teaching practices influence the relationship between social status and student achievement?]. *Teaching Innovations*, *30*(2), 29–41. https://doi.org/10.5937/inovacije2002029G

Hacieminoglu, E. (2016). Elementary school students' attitude toward science and related variables. *International Journal of Environmental and Science Education*, *11*(2), 35–52. https://doi.org/10.12973/ijese.2016.288a

Ho, M. T., La, V. P., Nguyen, M. H., Pham, T. H., Vuong, T. T., Vuong, H. M., Pham, H. H., Hoang, A. D., & Vuong, Q. H. (2020). An analytical view on STEM education and outcomes: Examples of the social gap and gender disparity in Vietnam. *Children and Youth Services Review*, *119*, Article 105650. https://doi.org/10.1016/j.childyouth.2020.105650

Hoffmeyer-Zlotnik, J. H. P., & Warner, U. (2007). How to survey education for cross-national comparison: The Hoffmeyer-Zlotnik/Warner-Matrix of education. *Metodološki zvezki, 4*(2), 117–148.

Holmes, K., Gore, J., Smith, M., & Lloyd, A. (2018). An integrated analysis of school students' aspirations for STEM careers: Which student and school factors are most predictive?. *International Journal of Science and Mathematics Education*, *16*, 655–675. https://doi.org/10.1007/s10763-016-9793-z

Hrnčić, J., Radovanović, M. & Burgund, A. (2014.) Rodne razlike u interesovanju učenika/ca za oblasti rada i zanimanja [Gender differences in students' interest in work and professions]. In: D. Duhaček (Ed.). *Obrazovanje, rod građanski status* [Education, gender, civil status] (pp. 143–155). Faculty of political sciences, center for gender and politics studies.

Hsieh, T. L., & Yu, P. (2022). Exploring achievement motivation, student engagement, and learning outcomes for STEM college students in Taiwan through the lenses of gender differences and multiple pathways. *Research in Science & Technological Education*, *41*(3), 1072–1087. https://doi.org/10.1080/02635143.2021.1983796

Ing, M. (2014), Gender differences in the influence of early perceived parental support on student mathematics and science achievement and STEM career attainment. *International Journal of Science and Mathematics Education*, *12*, 1221–1239. https://doi.org/10.1007/s10763-013-9447-3

Ivić, I. (2023). Kritička analiza stanja u obrazovanju i obrazovne politike u Srbiji [Critical analysis of the state of education and education policy in Serbia]. In: A. Kostić & A. Pešikan (Eds.), *Obrazovanje: stanje, perspektive i uloga u razvoju Srbije* [Education: state, perspectives and role in the development of Serbia] (pp. 39–82). SANU.

Japashov, N., Naushabekov, Z., Ongarbayev, S., Postiglione, A., & Balta N. (2022). STEM career interest of Kazakhstani middle and high school students. *Education Sciences*, *12*, 397–414. https://doi.org/10.3390/educsci12060397

Jiang, S., Simpkins, S. D., & Eccles, J. S. (2020). Individuals' math and science motivation and their subsequent STEM choices and achievement in high school and college: A longitudinal study of gender and college generation status differences. *Developmental Psychology*, *56*(11), 2137–2151. https://doi.org/10.1037/dev0001110

Jodl, K. M., Michael, A., Malanchuk, O., Eccles, J. S., & Sameroff, A. (2001). Parents' roles in shaping early adolescents' occupational aspirations. *Child Development*, *72*(4), 1247–1265. https://doi.org/10.1111/1467-8624.00345

John, J., Insouvanh, K., & Robnett, R. (2022). The roles of gender identity, peer support, and math anxiety in middle school math achievement. *Journal Of Research On Adolescence*, *33,* 230–250. https://doi.org/10.1111/jora.12800

Kaleva, S., Pursiainen, J., Hakola, M., Rusanen, J., & Muukkonen, H. (2019). Students' reasons for STEM choices and the relationship of mathematics choice to university admission, *International Journal of STEM Education*, *6*(43) https://doi.org/10.1186/s40594-019-0196-x

https://doi.org/10.33225/jbse/25.24.360

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Kanny, M. A., Sax, L. J., & Riggers-Piehl, T. A. (2014). Investigating forty years of STEM research: How explanations for gender gap have evolved over time. *Journal of Women and Minorities in Science and Engineering*, *20*, 127–148. https://doi.org/10.1615/JWomenMinorScienEng.2014007246

Ketenci, T., Leroux, A., & Renken, M. (2020). Beyond student factors: A study of the impact on STEM career attainment. *Journal for STEM Education Research*, *3*, 368–386. https://doi.org/10.1007/s41979-020-00037-9

Kiernan, L., Walsh, M., & White, E. (2023). Gender in technology, engineering and design: Factors which influence low STEM subject uptake among females at third level. *International Journal of Technology and Design Education*, *33*, 497–520. https://doi.org/10.1007/s10798-022-09738-1

Kilpatrick, S., & Fraser, S. (2018). Using the STEM framework collegially for mentoring, peer learning and planning. *Professional Development in Education*, *45*(4), 614–626. https://doi.org/10.1080/19415257.2018.1463925

Koyunlu Ünlü, Z., & Dökme, I. (2020). Multivariate assessment of middle school students' interest in STEM career: A profile from Turkey. *Research in Science Education*, *50*(2), 1217–1231. https://doi.org/10.1007/s11165-018-9729-4

Lahelma, E. (2014). Troubling discourses on gender and education. *Educational Research*, *56*(2), 171–183. https://doi.org/10.1080/00131881.2014.898913

Laine, E., Veermans, M., Gegenfurtner, A., & Veermans, K. (2020). Individual interest and learning in secondary school STEM education. *Frontline Learning Research*, *8*(2), 90–108. https://doi.org/10.14786/flr.v8i2.461

Lefever, S., Dal M., & Matthíasdóttir, Á. (2006). Online data collection in academic research: advantages and limitations. *British Journal of Educational Technology, 38*(4), 574–582. https://doi.org/10.1111/j.1467-8535.2006.00638.x

Legewie, J., & DiPrete, T. A. (2014). The high school environment and the gender gap in science and engineering. *Sociology of Education*, *87*(4), 259–280. https://doi.org/10.1177/0038040714547770

Lichtenberger, E., & George- Jackson, C. (2013). Predicting high school students' interest in majoring in a STEM field: Insight into high school students' postsecondary plans. *Journal of Career and Technical Education*, *28*(1), 19–38. https://doi.org/10.21061/jcte.v28i1.571

Lissitsa, S., & Chachashvili-Bolotin, S. (2021). Occupational reproduction and mobility in STEM – Parental narratives of their child's occupational choice. *Educational Studies*, *49*(5), 713–729. https://doi.org/10.1080/03055698.2021.1884047

Liu, S., Xu, S. R., Xiao H., & Zhou, S. (2022). Exploring effect on primary school students' STEM attitude determined via structural equation modeling. *Journal of Baltic Science Education*, *21*(6), 1052–1068. https://doi.org/10.33225/jbse/22.21.1052

Luo, T., So, W., Wan, Z. H., & Li, W. C. (2021). STEM stereotypes predict students' STEM career interest via self-efficacy and outcome expectations. *International Journal of STEM Education*, *8*. https://doi.org/10.1186/s40594-021-00295-y

Maksimović, J. Ž., Osmanović, J. S., & Mamutović, A. S. (2020). Perspectives of STEM education regarding Serbian secondary school students' motivation for career choice. *Journal of Baltic Science Education*, *19*(6), 989–1007. https://doi.org/10.33225/jbse/20.19.989

Maksimović, A. (2023). Inclusion and gender equality in tertiary education in Serbia. In: S. Zuković (Ed.). *Pedagogija – Juče danas, sutra* [Pedagogy – Yesterday, today, tomorrow] (pp. 149–157). Faculty of Philosophy, University of Novi Sad.

Maksimović, A., Milenković, A., & Stašević, F. (2024). Percepcije o nastavnim predmetima i postignuća učenika kao činioci usmerenja ka matematici i prirodnim naukama [Students' perceptions of the teaching subjects and student achievements as factors of orientation towards mathematics and natural sciences in grammar school]. *Teaching Innovations*, *37*(3), 29–42. https://doi.org/10.5937/inovacije2403029M

Meece, J. L., Hutchins, B. C., Byun, S.-y., Farmer, T. W., Irvin, M. J., & Weiss, M. (2013). Preparing for adulthood: A recent examination of the alignment of rural youth's future educational and vocational aspirations. *Journal of Educational and Developmental Psychology*, *3*(2), 175–192. https://doi.org/10.5539/jedp.v3n2p175

Munn, M., Griswold, J., Starks, H., Fullerton, S., Viernes, C., Sipe, T., Brown, M., Dwight, C., Knuth, R., & Levias, S. (2018). Celebrating STEM in rural communities: A model for an inclusive science and engineering festival. *Journal of STEM Outreach*, *1*(1), 1–11. https://doi.org/10.15695/jstem/v1i1.4

Murphy, S., MacDonald, A., Wang, A. C., & Danaia, L. (2019). Towards an understanding of STEM engagement: A review of the literature on motivation and academic emotions. *Canadian Journal of Science, Mathematics and Technology Education*, *19*, 304–320. https://doi.org/10.1007/s42330-019-00054-w

Murphy, S. (2023). Leadership practices contributing to STEM education success at three rural Australian schools. *The Australian Educational Researcher*, *50*, 1049–1067. https://doi.org/10.1007/s13384-022-00541-4

National Science Board. (2022). *The state of U.S. science and engineering: U.S. S&E workforce* (NSB-2022-21). National Science Foundation. https://ncses.nsf.gov/pubs/nsb20221/

Naukkarinen, J. K., & Bairoh, S. (2020). STEM: A help or a hinderance in attracting more girls to engineering?. *Journal of Engineering Education*, *109*, 177–193. https://doi.org/10.1002/jee.20320

Nicolaou, N., Phan, P. H., & Stephan, U. (2021). The biological perspective in entrepreneurship research. *Entrepreneurship Theory and Practice*, *45*(1), 3–17. https://doi.org/10.1177/1042258720967314

Nissinen, K., Ólafsson, R. F., Rautopuro, J., & Vettenranta, J. (2018). 7. The urban advantage in education? Science achievement differences between metropolitan and other areas in Finland and Iceland in PISA 2015. *Northern Lights on TIMSS and PISA*. https://doi.org/10.6027/E30B9E1C-EN

Nugent, G., Barker, B., Welch, G., Grandgenett, N., Wu, C., & Nelson, C. (2015). A model of factors contributing to STEM learning and career orientation. *International Journal of Science Education*, *37*(7), 1067–1088. https://doi.org/10.1080/09500693.2015.1017863

Nylund, M., Rosvall, P. A., Eiríksdóttir, E., Holm, A. S., Isopahkala-Bouret, U., Niemi, A. M., & Ragnarsdóttir, G. (2018). The academic–vocational divide in three Nordic countries: implications for social class and gender, *Education Inquiry*, *9*(1), 97–121. https://doi.org/10.1080/20004508.2018.1424490

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

OECD (2013). *PISA 2012 Assessment and analytical framework: Mathematics, reading, science, problem solving and financial literacy*. OECD Publishing.

Ozfidan, B., Duman, J., & Aydin, H. (2020). Parents' perceptions in STEM-oriented public schools: Correlations among ethnic, linguistic, and socio-cultural factors. *Educational Studies*, *48*(4), 562–582. https://doi.org/10.1080/03055698.2020.1793299

Peterson, B., Bornemann, G., Lydon, C., & West, K. (2015). Rural students in Washington State: STEM as a strategy for building rigor, postsecondary aspirations, and relevant career opportunities. *Peabody Journal of Education*, *90*(2), 280–293. https://doi.org/10.1080/0161956X.2015.1022397

Perera, L. D. H. (2014). Parents' attitudes towards science and their children's science achievement. *International Journal of Science Education*, *36*(18), 3021–3041. https://doi.org/10.1080/09500693.2014.949900

Pertiwi, N. P., Saputro, S., Yamtinah, S., & Kamari, A. (2024). Enhancing critical thinking skills through STEM problem-based contextual learning: An integrated e-module education website with virtual experiments. *Journal of Baltic Science Education*, *23*(4), 739–766. https://doi.org/10.33225/jbse/24.23.739

Pihl, J., Holm, G., Riitaoja, A. L., Kjaran I. J., & Carlson, C. (2018). Nordic discourses on marginalisation through education. *Education Inquiry*, *9*(1), 22–39. https://doi.org/10.1080/20004508.2018.1428032

Prix, I., & Kilpi-Jakonen, E. (2022). Not in a class of one's own: Social origin differentials in applying to gender-(a)typical fields of study across the educational hierarchy, *European Sociological Review*, *38*(6), 920–941. https://doi.org/10.1093/esr/jcac007

Radišić, J., Krstić, K., Blažanin, B., Mićić, K., Baucal, A., Peixoto, F., & Schukajlow, S. (2024). Am I a math person? Linking math identity with students' motivation for mathematics and achievement. *European Journal of Psychology of Education*, *39*, 1513–1536. https://doi.org/10.1007/s10212-024-00811-y

Saavedra, L. Ã., Araújo, A. M., Taveira, M. D., & Vieira, C. C. (2014). Dilemmas of girls and women in engineering: A study in Portugal. *Educational Review*, *66*(3), 330–344. https://doi.org/10.1080/00131911.2013.780006

Saleem, N., Mian, A., Saleem, H. I., & Rao, M. S. (2014). Career selection: Role of parents' profession mass media and personal choice. *Bulletin of Education and Research*, *36*(2), 25–37.

Schleicher, A. (2019). *PISA 2018: Insights and interpretation*. OECD Publishing.

Schleicher, A., & Zoido, P. (2016). Global equality of educational opportunity: Creating the conditions for all students to succeed. *Journal of Social Issues*, *72*(4), 696–719. https://doi.org/10.1111/josi.12190

Seyranian, V., Madva, A., Duong, N., Abramzon, N., Tibbetts, Y., & Harackiewicz, J. M. (2018). The longitudinal effects of STEM identity and gender on flourishing and achievement in college physics. *International Journal of STEM Education*, *5*(40). https://doi.org/10.1186/s40594-018-0137-0

Shahbazian, R. (2021). Under the influence of our older brother and sister: the association between sibling gender configuration and STEM degrees. *Social Science Research*, *97*, Article 102558. https://doi.org/10.1016/j.ssresearch.2021.102558

Sheldrake, R., & Mujtaba, T. (2020). Children's aspirations towards science-related careers. *Canadian Journal of Science, Mathematics and Technology Education*, *20*, 7–26. https://doi.org/10.1007/s42330-019-00070-w

Showalter, D., Klein, R., Johnson, J., & Hartman, S. L. (2017). *Why rural matters 2015-2016: understanding the changing landscape*. A report of the rural school and community trust. Rural school and community trust. https://eric.ed.gov/?id=ED590169

Siew, N. M., Goh, H., & Sulaiman, F. (2016). Integrating STEM in an engineering design process: The learning experience of rural secondary school students in an outreach challenge program. *Journal of Baltic Science Education*, *15*(4), 477–493. https://doi.org/10.33225/jbse/16.15.477

Sinnes, A., & Løken, M. (2014). Gendered education in a gendered world: looking beyond cosmetic solutions to the gender gap in science. *Cultural Studies of Science Education*, *9*, 343–364. https://doi.org/10.1007/s11422-012-9433-z

Siregar, N. C., Rosli, R., & Nite, S. (2023). Students' interest in science, technology, engineering, and mathematics (STEM) based on parental education and gender factors. *International Electronic Journal of Mathematics Education*, *18*(2), Article em0736. https://doi.org/10.29333/iejme/13060

Song, C. S., Xu, C., Maloney, E. A., Skwarchuk, S. L., Di Lonardo Burr, S., Lafay, A., Wylie, J., Osana, H. P., Douglas , H., & LeFevre, J. A. (2021). Longitudinal relations between young students' feelings about mathematics and arithmetic performance. *Cognitive Development*, *59*, Article 101078. https://doi.org/10.1016/j.cogdev.2021.101078

Starr, C. R., Ramos Carranza, P., & Simpkins, S. D. (2022). Stability and changes in high school students' STEM career expectations: Variability based on STEM support and parent education. *Journal of Adolescence*, *94*(6), 906–919. https://doi.org/10.1002/jad.12067

Statistical Office of the Republic of Serbia (2022). *Number of enrolled students by gender and fields of education*. Statistical office of the Republic of Serbia. https://data.stat.gov.rs/Home/Result/11040104?languageCode=sr-Latn

Svoboda, R. C., Rozek, C. S., Hyde, J. S., Harackiewicz, J. M., & Destin, M. (2016). Understanding the relationship between parental education and STEM course taking through identity-based and expectancy-value theories of motivation. *American Educational Research Journal*, *2*(3). https://doi.org/10.1177/2332858416664875

Ševkušić, S. (2022). Professional interests of final grade primary school students in Serbia: A case study. In J. Stevanović, D. Gundogan & B. Ranđelović (Eds.), *The State, problems, and needs of modern education community* (pp. 35–44). Institute of Educational Research.

Šimunović, M., Reić Ercegovac, I., & Burušić, J. (2018). How important is it to my parents? Transmission of STEM academic values: The role of parents' values and practices and children's perceptions of parental influences. *International Journal of Science Education*, *40*(9), 977–995. https://doi.org/10.1080/09500693.2018.1460696

Šimunović, M., & Babarović, T. (2020). The role of parents' beliefs in students' motivation, achievement, and choices in the STEM domain: A review and directions for future research. *Social Psychology of Education*, *23*(3), 701–719. https://doi.org/10.1007/s11218-020-09555-1

Thomson, S., Wernert, N., O'Grady, E., & Rodrigues, S. (2017). *TIMSS 2015: Reporting Australia's results*. Australian council of educational research. https://research.acer.edu.au/timss_2015/2/

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Thomson, S., De Bortoli, L., Underwood, C., & Schmid, M. (2019). *PISA 2018: Reporting Australia's results*. Australian council of educational research. https://research.acer.edu.au/ozpisa/35/

van der Vleuten, M., Jaspers, E., Maas, I., & van der Lippe, T. (2016). Boys' and girls' educational choices in secondary education. The role of gender ideology. *Educational Studies*, *42*(2), 181–200. https://doi.org/10.1080/03055698.2016.1160821

van Tuijl, C., & van der Molen, J. H. W. (2016). Study choice and career development in STEM fields: an overview and integration of the research. *International Journal of Technology and Design Education*, *26*, 159–183. https://doi.org/10.1007/s10798-015-9308-1

Vidić, T., & Đuranović, M. (2020). Students' attitudes towards mathematics and their perceptions of teacher support, enthusiasm, classroom management and their own behavior. *Journal of Educational Science and Psychology*, *10*(2), 61–73.

Wakhata, R., Mutarutinya, V., & Balimuttajjo, S. (2022). Secondary school students' attitude towards mathematics word problems. *Humanities and Social Sciences Communications*, *9*(1) https://doi.org/10.1057/s41599-022-01449-1

Weeden, K. A., Gelbgiser, D., & Morgan, S. L. (2020). Pipeline dreams: Occupational plans and gender differences in STEM major persistence and completion. *Sociology of Education*, *93*(4), 297–314. https://doi.org/10.1177/0038040720928484

Zakon o osnovama sistema obrazovanja i vaspitanja Republike Srbije [The law on the foundations of the education system in the Republic of Serbia]. Official Gazette, 2024. https://www.paragraf.rs/propisi/zakon_o_osnovama_sistema_obrazovanja_i_vaspitanja.html

Appendix

Instrument

1. Gender
    - a) male
    - b) female

2. Department
    - a) natural sciences and mathematics department
    - b) socio-linguistic department
    - c) general stream of studies
    - d) bilingual department,
    - e) specialized department for sports
    - f) specialized department for philology
    - g) specialized department for mathematics
    - h) specialized department for computer science
    - i) specialized department for physics
    - j) specialized department for biology and chemistry.

3. I grew up in:
    - a) Rural locality
    - b) Urban locality

4. Grammar school which I attend is:
    - a) First Grammar school in Kragujevac
    - b) Second Grammar school in Kragujevac
    - c) Grammar school „Svetozar Marković" in Novi Sad
    - d) Grammar school „Jovan Jovanović Zmaj" in Novi Sad

5. Mother' s educational level:
    - a) Primary education degree
    - b) Secondary education degree
    - c) Bachelor's degree
    - d) Master's degree

6. Father' s educational level:
    - a) Primary education degree
    - b) Secondary education degree
    - c) Bachelor's degree
    - d) Master's degree

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7. How many children are there in your family, including yourself? (Enter the number): _________

8. Write down the most frequent end-of-term grade you received in the given subject during your primary school education:

a) Biology_____
b) Physics_____
c) Chemistry_____
d) Mathematics_____
e) Computer Science ____
f) Technical education and technology ____

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RESEARCH LITERACY, SOCIO-SCIENTIFIC REASONING, AND PROBLEM-SOLVING SKILLS IN SCIENCE TEACHERS

Savaş Varlık

Abstract. *This research is a comprehensive mixed-methods study that aims to examine in depth the correlations between science teachers' research literacy, socio-scientific reasoning, and problem-solving skills. The quantitative phase of the research was conducted using a descriptive survey method, while the qualitative phase employed a case study design. The study population consists of science teachers working in the central districts of Konya, and Türkiye. For sample selection, stratified and random sampling techniques were used for the quantitative data, and purposive sampling techniques were applied for the qualitative data. Confirmatory factor analysis and reliability analyses were conducted using the three different measurement tools used in the study. A semi-structured interview form was utilized to collect qualitative data. The quantitative findings revealed that research literacy and socio-scientific reasoning skills significantly and positively predict problem-solving skills. The qualitative findings indicated that these skills mutually reinforce each other, enhancing students' scientific and analytical thinking capacities and enabling them to develop creative solutions to real-life problems. In this context, the evidence presented indicates that educational policies should focus on fostering these skills through a comprehensive approach, with greater emphasis on integrating innovative methods into science curricula.*

Keywords: *mixed methods research, problem-solving, research literacy, science teachers, socio-scientific reasoning*

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Introduction

Today's education systems aim to educate students with the skills required by the information age. In line with this purpose, it aims to develop students' competencies in accessing, evaluating, and using information by providing them with research literacy; to gain a critical and ethical perspective on scientific and social issues with socio-scientific reasoning skills; and to enable them to produce creative and analytical solutions to complex problems they encounter with problem-solving skills. Especially in this respect, science education stands out as an important discipline that contributes to the development of students' critical thinking (Adams, 2024), scientific inquiry (Seher Budak & Defne Ceyhan, 2023), problem-solving and socio-scientific reasoning skills (Gillies, 2024). In this context, it is critical for science teachers to have these skills (Herranen & Aksela, 2019) and to effectively reflect these competencies in teaching processes (Johnson, 2024). However, when the existing literature is examined (Filho et al., 2024; Heikkilä & Eriksen, 2023; Muchlas Abrori et al., 2023), it is seen that the correlations between science teachers' research literacy, socio-scientific reasoning, and problem-solving skills have not been systematically addressed and there is a significant research gap in these areas. Research literacy refers to teachers' ability to access scientific knowledge (Beaudry & Miller, 2016), critically evaluate this knowledge (McGregor, 2018), and use this knowledge in the classroom environment (Shank et al., 2018). This skill is essential for teachers to keep up with constantly changing and updated scientific knowledge (Menard, 2003) and to guide their students in this direction (Davis, 2008). Similarly, socio-scientific reasoning refers to students' capacity to think analytically and make logical inferences on scientific issues (Filho et al., 2024), including environmental, ethical, and social dimensions (Karukstis & Elgren, 2007). This directly affects teachers' ability to discuss complex socio-scientific issues in the modern world with students (Knain, 2015). Problem-solving skill, on the other hand, enables teachers to develop creative solutions to the problems they encounter in their professional lives (Rizvi, 2024) and to provide this skill to students (Musa, 2024).

Literature Review

Addressing the correlation between research literacy, socio-scientific reasoning, and problem-solving skills through theoretical approaches and

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theories offers an in-depth perspective in terms of education and scientific thinking. Research literacy includes students' ability to access, evaluate, and apply scientific knowledge (Shank & Brown, 2007). In terms of research literacy, information processing theory provides a basic approach to explain this process (Bettman, 1979). According to this theory, students go through the processes of perceiving, processing, storing, and recalling information (Kmetz, 2018). Effective management of these processes strengthens research literacy (Bettman, 1979). Socio-scientific reasoning is the ability of students to solve problems (Shah, 2019) by using scientific knowledge in a social context (Uyanık, 2024). This process can be explained by Lev Vygotsky's socio-cultural theory. Vygotsky has emphasized the role of social interactions and cultural tools in students' cognitive development (Garg, 2023). Socio-scientific reasoning involves students making decisions by taking into account social and ethical values and this process is enriched by social interactions (Fındık, 2024). Vygotsky's concept of the zone of proximal development states that students can learn more complex tasks in interaction with others, and this plays a critical role in the development of socio-scientific reasoning (Garg, 2023). Problem-solving skills refer to students' ability to identify (Wallace et al., 2013), analyze (Sinha, 2020), and solve the problems they face (Attri, 2018). Gestalt theory offers an important perspective on the problem-solving process. This theory states that students try to solve problems from a holistic perspective, not by breaking them into parts (Wertheimer & King, 2005). In the problem-solving process, it is important for students to find solutions by mentally restructuring (Petermann, 2013). This enables students to adapt their existing knowledge and experiences to new situations (Wertheimer & King, 2005). Furthermore, this theoretical framework shows how research literacy, socio-scientific reasoning, and problem-solving skills interact and support each other. Research literacy strengthens students' ability to understand, evaluate, and apply scientific knowledge (Sambey, 2016). This knowledge gains meaning in the social context to be used in socio-scientific reasoning processes (Abell, 2007). Socio-scientific reasoning enables students to make more in-depth and informed decisions (Powel, 2021) by using scientific knowledge in a social and ethical context (Sadler, 2021). Problem-solving skills, on the other hand, allow students to approach the problems they face from a holistic perspective (Beghetto, 2018) and produce effective solutions (Zheng, 2023). This process requires students to adapt their existing knowledge and experiences to new situations through mental restructuring (Hiremath, 2024). Research literacy, socio-scientific reasoning, and problem-solving skills are important skills that interact with each other (Shank et al., 2018) and contribute to students' more conscious, critical, and effective thinking (Beaudry & Miller, 2016). These abilities include students' processes of understanding, evaluating, using scientific knowledge in a social context, and producing effective solutions (McGregor, 2018). Although it is seen that these three basic skills are addressed separately in the existing studies in the literature (Heikkilä & Eriksen, 2023; Langner & Graulich, 2024; Muchlas Abrori et al., 2023; Orhan & Genç, 2024; Shattuck, 2020; Ventistas et al., 2024), it has been limited to evaluate them together and examine their effects on science teachers' professional competences with a holistic approach (Akpan et al., 2023; Allchin et al., 2024). This situation leads to deficiencies in designing policies and strategies to improve science teachers' skills in these areas (Ong et al., 2024). In fact, Çıldır and Acarlı (2024) have drawn attention to this gap and made suggestions for science teachers in their research. Therefore, this study aims to fill the knowledge gap in this field by comprehensively examining the correlations between science teachers' research literacy, socio-scientific reasoning, and problem-solving skills. In the research, both quantitative and qualitative data are collected and analyzed by adopting a mixed-method approach (Creswell & Guetterman, 2019). While quantitative research determines the current levels of the subject (Adams & Mcguire, 2023), qualitative research offers an in-depth examination opportunity for researchers (Okoko et al., 2023). At the end of this study, an educational model or strategy proposal is put forward to develop science teachers' research literacy, socio-scientific reasoning, and problem-solving skills. This model aims to provide a concrete guide for teacher training programs, professional development activities, and educational policies. In addition, practical tools and resources are developed to enable science teachers to effectively integrate these skills into the classroom environment. The research findings are expected to provide valuable information for academics, policymakers, curriculum developers, and teachers who contribute to science teacher education. In light of this information, the research questions are presented below.

Research Questions

1) How do teachers perceive and define the correlations among research literacy, socio-scientific reasoning, and problem-solving skills?
2) Do research literacy and socio-scientific reasoning predict problem-solving skills?

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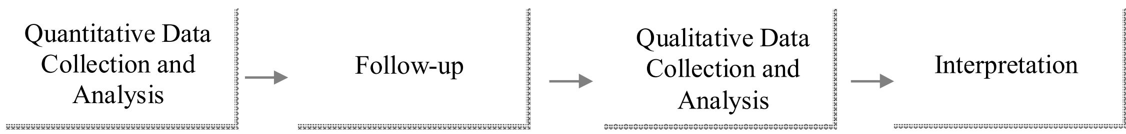
Research Methodology

Design

This study is a mixed-method research that aims to comprehensively examine the correlations among science teachers' research literacy, socio-scientific reasoning, and problem-solving skills. Mixed method research is a research method in which quantitative and qualitative research methods are used together (Creamer, 2025). This method provides a more in-depth and comprehensive analysis by combining different types of data (Mertens, 2023). The study was conducted with the explanatory sequential design of mixed-method research (Fetters, 2020; Johnson & Christensen, 2020). The mixed explanatory sequential design is a mixed method research design in which quantitative data are first collected and analyzed, and then these results are supported by qualitative data and explained in more depth. The model for the research design is given in Figure 1.

Figure 1
Mixed Exploratory Sequential Pattern



The research design starts with the collection and analysis of quantitative data and ends with the interpretation of the qualitative data collection and analysis process with the follow-up phase. The quantitative design of the research is a descriptive survey model. The quantitative descriptive survey is a research design that aims to describe a situation or phenomenon as it is and to describe the current situation with numerical data (Phiri, 2024). The qualitative design of the research is a case study design. A qualitative case study design is a qualitative research design that aims to examine a situation, event, or process in depth and detail (Wahyuni, 2024). The research was conducted between 02 May 2024 and 05 January 2025.

Sampling

The research was conducted in the Karatay, Meram, and Selçuklu districts of Konya province in Türkiye. According to the data obtained from the Konya Directorate of National Education, the number of Science Teachers working in the Karatay district is 138, the number of Science Teachers working in the Meram district is 141, and the number of Science Teachers working in Selçuklu district is 159. There are 438 teachers in total in these three districts. In the calculation made by taking α = .05 into account for the quantitative part of the study, if ± > 205 teachers are reached, the sample represents the population (Blair et al., 2023). Accordingly, science teachers in the study population were included in the study by stratified sampling and random sampling technique [Stratification Coefficient: 438/205 = 0.468037; Karatay: ± 66, Meram: ± 67, Selçuklu: ± 74]. Stratified sampling is a sampling technique that involves dividing the population into subgroups (strata) and selecting samples proportionally from each stratum (Hiebert et al., 2023). Random sampling is a completely random sampling technique in which each unit is selected equally and independently (Zou & Xu, 2023). The schools where the teachers work were selected as the sampling unit and the number of science teachers working in these schools was listed. Then, with the help of a computer program, it was decided in which schools the research should be conducted. Then, these teachers were reached on a voluntary basis. In this respect, 31,9% (n = 66) from the Karatay district, 32,4% (n = 67) from the Meram district, and 35,7% (n = 74) from the Selçuklu district participated in the study. The average age of the teachers who participated in the study was 48,75 ± 12,84 and the average professional seniority was 22,14 ± 3,46. Of the Science Teachers participating in the study, 53,6 % (n = 111) were female and 46,4 % (n = 96) were female. In addition, 85,5% (n = 177) of them are Expert Teachers and 14,5% (n = 30) of them are Head Teachers. In the qualitative part of the research, (n = 7) teachers from the field of science (n = 7) in the quantitative part sample were selected on a voluntary basis. In the selection of teachers, a purposeful sampling sub-sample criterion sampling technique was used. In the selection of science teachers, *"being on active duty at least in the title of expert or head teacher and having a professional seniority of twenty years or more"* were determined as criteria. Qualitative purposive sampling

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is a sampling technique in which participants who are most appropriate for the research questions and who can provide information are consciously selected (Savin-Baden & Major, 2022). This research was conducted with the decision taken by Akdeniz University Social and Human Sciences Scientific Research and Publication Ethics Committee on 16.11.2024 with the number 26.

Data Collection Tools

In the quantitative part of the study, the research literacy skills scale consisting of twenty-six items developed by Yıldız et al. (2019), the socio-scientific reasoning skills scale consisting of eighteen items developed by Çıldır and Acarlı (2024), problem-solving skills scale consisting of eighteen items developed by Yaman and Dede (2008) were used. The high scores obtained from research literacy, socio-scientific reasoning, and problem-solving skills scales indicate that teachers have strong abilities and skills in these areas. All of the scale items were positive and were subjected to the classification of '1- Strongly Disagree, 5-Strongly Agree' and applied face-to-face. Confirmatory factor analysis and reliability analyses were performed for the scales. Research literacy skills scale CMIN/DF 1.467, p-value .185, RMSEA value .048, SRMR value .009, CFI value, .959, GFI value .986; socio-scientific reasoning skills scale CMIN/DF 1.467, p-value. 185, RMSEA value .048, SRMR value .009, CFI value, .959, GFI value .986; problem solving skills scale CMIN/DF 2.055, p-value .017, RMSEA value .072, SRMR value .014, CFI value, .984, GFI value .970. These values confirmed the validity of the measurement tools (Chen & Yung, 2023; Newsom, 2024). Research literacy skills scale McDonald's omega ω=.780, socio-scientific reasoning skills scale McDonald's omega ω=.831, problem-solving skills scale McDonald's omega ω=.811. These values showed that the measurement tools were reliable (Cipresso & Immekus, 2022). In the qualitative part of the study, a semi-structured interview form was developed. Semi-structured interview form is a research technique used to collect information about a specific topic (Denzin & Lincoln, 2018; Flick, 2022). The interviews with the participants lasted approximately forty to seventy minutes. The interviews with the participants were conducted in a sincere environment, and the answers to the questions were deepened with 'Why?' and 'How?' questions. The interviews were audio-recorded with participants' written consent. In qualitative research, validity and reliability are approached differently than in quantitative research. Credibility ensures accuracy, transferability assesses applicability, reliability evaluates consistency, and confirmability establishes impartiality. The researcher's field notes, serving as self-reflexive diaries, support the hermeneutic interpretation of data, which is essential for understanding participants' perspectives and experiences (Gunbayi, 2024). From this point of view, validity refers to the accuracy of the research and reliability refers to its consistency. In this research, these concepts were achieved by analyzing the data in depth and contextually. The interview transcripts regarding the validity and reliability of qualitative analyses are given in the sub-sections of the theme analysis.

Data Analysis

Linearity, multiple linear connections, multiple normality, and independence assumptions were tested for the measurement tools (Frey, 2018). These assumptions of the measurement tools were verified. In the study, reference values for skewness and kurtosis values were determined as ±3 (Denscombe, 2020). Accordingly, the skewness value of the research literacy skills scale was -.491, kurtosis value was .632; the skewness value of the socio-scientific reasoning skills scale was -1.636, kurtosis value was 2.448; the skewness value of the problem-solving skills scale was -1.504, kurtosis value was 2.623. These values showed that the measurement tools were normally distributed (Crano et al., 2023). JAMOVI 2.4.2 package program was used in the quantitative part of the study. After determining that the data were normally distributed, Pearson correlation analysis was performed. Then, regression analysis was performed for the prediction of problem-solving by research literacy and socio-scientific reasoning. The assumptions of the regression analysis were made and given under the relevant table. Qualitative analyses were conducted with the NVIVO 14 package program concerning Gunbayi (2023). The data obtained from in-depth interviews with teachers were first transcribed and then subjected to a qualitative data analysis process. In the first step, the interviews were recorded and transcribed verbatim. The transcripts were read repeatedly to get a preliminary idea about the general structure and content of the data. In the second step, after the initial review of the data, the content analysis method was used to identify important statements, concepts, and themes in the data. In the third step, the codes were grouped according to their similar characteristics, and categories were formed. At this stage, the correlations and thematic connections between codes were analyzed. In the fourth step, themes were formed by analyzing the correlations between categories and general trends. At this stage, it was analyzed how the categories were related to each other and how they answered the research

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questions. In the last step, to ensure the reliability of the analysis process, the codes, categories, and themes were discussed among the researchers, and the consensus points were determined. In addition, to test the consistency of the findings, some of the data were analyzed by five independent researchers, and the results were compared. Fleiss Kappa reliability coefficient $K = .853$ $p = .001$ was calculated for the data at the end of the study. This value showed that the level of reliability between the practitioners was high (Gwet, 2021). Ethically, the names of the participants were coded as *"A, B, C, D, E, F, G".*

Research Results

Quantitative Results

Information about the distribution levels of teachers' perceptions of research literacy, socio-scientific reasoning, and problem-solving skills and the correlation between research literacy, socio-scientific reasoning, and problem-solving skills are given in Table 1, and information about whether research literacy and socio-scientific reasoning predict problem-solving skills is given in Table 2.

Table 1
Descriptive statistical analysis results regarding the distribution levels of measurement tools

Scales	Y_1	Y_2	Y_3	*M*	*SD*
Research Literacy (Y_1)	1			4.13	0.236
Socio-Scientific Reasoning (Y_2)	.431**	1		4.10	0.294
Problem-Solving (Y_3)	.700**	.870**	1	4.14	0.276

$*p < .05$; $**p < .01$; $***p < .001$, $N = 207$

When Table 1 is analyzed, it is seen that the participants had high levels of research literacy ($M = 4.13$, $SD = 0.236$), socio-scientific reasoning ($M = 4.10$, $SD = 0.294$), and problem-solving ($M = 4.14$, $SD = 0.276$). Correlation analyses show that there are statistically significant positive correlations between research literacy and socio-scientific reasoning ($r = .431$, $p < .01$), research literacy and problem-solving ($r = .700$, $p < .01$), and socio-scientific reasoning and problem-solving ($r = .870$, $p < .01$). These findings indicate that there is a strong correlation between the three variables.

Table 2
Results of regression analyses on research literacy and socio-scientific reasoning predicting problem-solving skills

Variables	β	*SE*	*t*	*p*	R^2	Problem-Solving ($\hat{Y}$)	
						Tolerance	VIF
Research Literacy (X_1)	.400	,031	15.292	.001***	.887	.814	1.228
Socio-Scientific Reasoning (X_2)	.697	.024	26.681	.001***			

$*p < .05$; $**p < .01$; $***p < .001$, $N = 207$, Beta coefficient values are given as standardized. R value was .942, R^2 value was .887, adjusted R^2 value was .887, $F_{(2\text{-}204)} = 796.862$, Durbin Watson value was 1.791.

According to Table 2, research literacy (β = .400, $p < .001$) and socio-scientific reasoning (β = .697, $p < .001$) significantly and positively affect problem-solving skills. The regression model explained 88.7% of the variance in problem-solving ($R^2 = .887$) and the appropriateness of the model was supported by $F_{(2, 204)} = 796.862$, $p < .001$. These findings indicate that both variables play a strong determinant role in problem-solving.

Qualitative Results

Information on how science teachers perceive and define the correlations between research literacy, socio-scientific reasoning, and problem-solving skills are given in Table 3, Table 4, and Table 5.

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Table 3
Theme Analysis for the İdentification of Research Literacy, Socio-scientific Reasoning, and Problem-solving Skills

Theme	Category	Code	Participants
Research Literacy Skills	Scientific Process and Critical View	Research literacy is the ability of students to understand and apply scientific research processes and to look critically at information.	A, B, C, D, E, F, G
	Data Collection and Analysis	Research literacy includes the ability to collect and analyze data.	A, B, E, F, G
Socio-Scientific Reasoning Skills	Social and Ethical Context	Socio-scientific reasoning is the ability to understand society in the context of ethical values.	A, B, E, F, G
	Social and Ethical Evaluation	Socio-scientific reasoning is the ability to evaluate scientific knowledge in a social and ethical context.	C, D, G
Problem-solving Skills	Identification, Analysis and Solution Generation	Problem-solving skills are the ability to identify, analyze, and produce effective solutions to problems encountered.	A, B, C, D, E, F, G
	Creative and Strategic Thinking	Problem-solving skills include the capacity for creative thinking and strategic planning.	B, F, G

When Table 3 is analyzed, information on how science teachers define research literacy, socio-scientific reasoning, and problem-solving skills is given below.

In line with the teachers' views, it was determined that research literacy includes skills such as looking critically at scientific knowledge, accessing knowledge using scientific methods, collecting and analyzing data, and reading and understanding scientific literature. For example, one teacher emphasized the importance of students' understanding and application of scientific research processes and said: *"...it is important for students to understand and apply scientific research processes. Thus, they can question scientific knowledge and make their decisions accordingly." [A]*. Similarly, another teacher stated that research literacy provides the ability to use scientific methods effectively: *"...research literacy provides the ability to use scientific methods effectively." [B]*. In addition, one of the teachers stated that students should be able to read and understand scientific literature and generate new knowledge: *"...students should be able to read and understand scientific literature and generate new knowledge." [C]*.

Teachers stated that socio-scientific reasoning includes skills such as evaluating scientific knowledge in a social and ethical context, applying scientific knowledge in daily life, and making moral and logical decisions. For example, one teacher emphasized the importance of analyzing scientific knowledge in correlation to social problems: *"...it is very important to be able to analyze scientific knowledge in correlation to social problems." [D]*. Another teacher stated that students should be able to make ethical evaluations about scientific issues: *"...students should be able to make ethical evaluations about scientific issues." [E]*. Moreover, one teacher stated that discussing the ethical aspects of scientific developments in society enables students to think critically: *"...discussing the ethical aspects of scientific developments in society enables students to think critically." [F]*.

Teachers emphasized aspects of problem-solving skills such as defining and analyzing the problem, generating solutions using scientific methods, and strategic and creative thinking. For example, one teacher stated that students should solve the problems they encounter by using scientific methods: *"...students should solve the problems they face by using scientific methods." [G]*. Another teacher emphasized that problem-solving skills require creative thinking and strategic planning: *"... problem-solving skills require students to think creatively and make strategic planning." [A]*. Moreover, one teacher stated that analyzing complex situations and developing alternative solutions are the basis of this skill: *"... analyzing complex situations and developing alternative solutions is the basis of this skill." [F]*.

Table 4
Theme Analysis of the Link between Research Literacy, Socio-scientific Reasoning and Problem Solving Skills

Theme	Category	Code	Participants
Research Literacy Skills	Access and Use of Scientific Knowledge	Research literacy increases students' access to scientific knowledge and their ability to use this knowledge.	A, B, F
	Critical View of Knowledge	Research literacy provides students with the ability to acquire and evaluate scientific knowledge.	C, D, G

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Theme	Category	Code	Participants
Socio-Scientific Reasoning Skills	Evaluation in Social and Ethical Context	Socio-scientific reasoning enables students to evaluate scientific knowledge in a social and ethical context.	A, B, E, F
	Social and Ethical Perspective	Socio-scientific reasoning enables evaluating knowledge within social and ethical contexts.	C, D, G
Problem-solving Skills	Generating Creative and Effective Solutions	Problem-solving skills enable students to use the acquired knowledge to solve real-world problems.	A, B, E, F, G
	Use of Scientific Method	Problem-solving skills involve generating creative, scientific solutions.	C, G

When Table 4 is analyzed, information about the connection between science teachers' research literacy, socio-scientific reasoning, and problem-solving skills is given below.

Under the theme of research literacy skills, teachers emphasized students' skills in accessing and using scientific knowledge and developing a critical perspective. Teachers stated that research literacy increases students' ability to access and use scientific knowledge. For example, one teacher stated that *"...research literacy facilitates students' access to scientific knowledge and enables them to use this knowledge in a meaningful way." [A]*. Similarly, another teacher drew attention to the importance of the ability to use scientific sources correctly and stated, *"... the ability to use scientific sources correctly is a critical point in students' research." [B*]. Moreover, one of the teachers emphasized the importance of students' reaching meaningful information by examining scientific literature: *"... students' access to meaningful information by analyzing scientific literature is an important part of research literacy." [F]*. Teachers stated that research literacy is not only limited to accessing information but also provides the ability to critically evaluate this information. For example, one teacher stated that *"...students should not only access scientific knowledge but also question its reliability." [C]*. Another teacher emphasized the importance of analyzing scientific knowledge and distinguishing correct knowledge and stated, *"... analyzing scientific knowledge and distinguishing correct and incorrect knowledge is the basis of research literacy." [D]*. Moreover, one teacher stated that a critical perspective enables students to be conscious individuals: *"...evaluating scientific knowledge from a critical perspective enables students to become more conscious individuals." [G]*.

Under the theme of socio-scientific reasoning skills, teachers emphasized that students should have the ability to evaluate scientific knowledge in an ethical and social context. Teachers stated that students should be able to evaluate scientific knowledge not only academically but also in a social and ethical context. For example, one teacher stated, *"...it is important to be able to evaluate the social consequences of using scientific knowledge." [A]*. Another teacher emphasized the necessity of analyzing the effects of scientific developments on society: *"... students should be able to analyze the effects of scientific developments on society." [B]*. Moreover, one teacher stated that scientific ethics enables students to evaluate their decisions within an ethical framework: *"...scientific ethics enables students to evaluate their decisions within an ethical framework." [E]*. Teachers stated that socio-scientific reasoning develops students' ability to consider scientific knowledge in the context of ethical and social issues. For example, one teacher said, *"...it is important not only to learn scientific knowledge but also to evaluate its social implications." [C]*. Another teacher emphasized that students should approach scientific knowledge knowing their ethical responsibilities: *"...students should approach scientific knowledge knowing their ethical responsibilities." [D]*.

Under the theme of problem-solving skills, teachers emphasized that students should be able to produce creative and effective solutions using scientific methods. Teachers stated that problem-solving skills are not only based on technical knowledge but also require creative and strategic thinking. For example, one teacher stated, *"... students should be able to apply the knowledge they have learned to real-life problems." [A]*. Another teacher emphasized the importance of transforming scientific knowledge into practical solutions: *"...scientific knowledge should not only be learned theoretically but should also be transformed into practical solutions." [B]*. Moreover, one teacher stated that creative thinking should be encouraged in the problem-solving process: *"...students should be encouraged to think creatively when dealing with complex problems." [G]*. Teachers emphasized that students should be able to produce systematic and logical solutions by using scientific methods in the problem-solving process. For example, one teacher said, *"...scientific methods enable students to generate systematic solutions to the problems they encounter." [C]*. Another teacher stated that scientific thinking supports creative approaches: *"...scientific thinking supports creative approaches in problem-solving." [C]*.

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Table 5
Theme Analysis on the Effect of Research Literacy and Socio-scientific Reasoning on Problem-solving Skills

Theme	Category	Code	Participants
Research Literacy Skills	Access to and Use of Scientific Knowledge	Research literacy develops students' ability to access and use scientific knowledge.	A, B, E, F, G
	Data Collection and Analysis	Research literacy develops students' ability to collect and analyze data and interpret results.	A, B, D
	Decisions based on scientific knowledge	Research literacy enables students to make decisions based on scientific knowledge in problem-solving processes.	C, F, G
Socio-Scientific Reasoning Skills	Social and Ethical Context	Socio-scientific reasoning enables students to evaluate scientific knowledge in a social and ethical context.	A, D, E, F, G
	Social and Ethical Evaluation	Socio-scientific reasoning contributes to students produce more comprehensive and effective solutions by considering social and ethical perspectives.	B, C
Problem-solving Skills	Creating Conscious and Effective Solutions	Problem-solving skills enable students to produce more conscious and effective solutions in problem-solving processes.	A, B, E, F, G
	In-Depth Solutions	Research literacy and socio-scientific reasoning support students to produce more in-depth and conscious solutions in the problem-solving process.	C, D

When Table 5 is analyzed, information about whether science teachers' research literacy and socio-scientific reasoning are effective on problem-solving skills is given below.

Under the theme of research literacy skills, teachers emphasized that students should develop the skills of accessing scientific knowledge, collecting and analyzing data, and making decisions based on scientific knowledge. Teachers stated that research literacy enables students to access scientific knowledge and use this knowledge effectively. For example, one teacher stated that *"...students should know how to access scientific knowledge and be able to use this knowledge in their own research." [A]*. Similarly, another teacher stated that research literacy teaches access to scientific resources and correct use of information: *"...research literacy teaches accessing scientific resources and using information correctly."* [B]. Moreover, one teacher emphasized that access to scientific knowledge encourages students' inquisitive and analytical thinking: *"...access to scientific knowledge encourages students' inquisitive and analytical thinking." [G]*. Teachers stated that research literacy develops students' skills in collecting and analyzing scientific data and interpreting the results. For example, one teacher stated that *"...collecting and analyzing scientific data is one of the most critical steps in the research process." [A]*. Another teacher stated that students should draw meaningful conclusions by analyzing data: *"...students should not only access information but also analyze data and draw meaningful conclusions." [B]*. Teachers stated that research literacy enables students to make decisions based on scientific knowledge in problem-solving processes. For example, one teacher stated that *"...making decisions based on scientific knowledge develops students' critical and conscious thinking skills." [C]*. Another teacher emphasized that decisions based on scientific knowledge improve the quality of the problem-solving process: *"...making decisions based on scientific knowledge improves the quality of the problem-solving process." [G]*.

Under the theme of socio-scientific reasoning skills, teachers emphasized that students should have the ability to evaluate scientific knowledge in an ethical and social context and to produce effective solutions by considering social and ethical perspectives. Teachers stated that socio-scientific reasoning provides the ability to evaluate scientific knowledge in a social and ethical context. For example, one teacher said, *"...students should consider social and ethical aspects when evaluating scientific knowledge." [A]*. Another teacher stated that scientific ethics enables students to evaluate scientific developments more comprehensively: *"...scientific ethics allows students to evaluate scientific developments more comprehensively." [E]*. Teachers stated that it contributed to students producing more comprehensive and effective solutions by considering social and ethical perspectives. For example, one teacher stated, *"...evaluating scientific knowledge with ethical and social aspects enables students to make more informed decisions." [B]*. Another teacher emphasized that understanding the correlation between society and science encourages students to think critically: *"...understanding the correlation between society and science encourages students to think critically." [C]*.

Under the theme of problem-solving skills, teachers emphasized that students should acquire the skills to produce conscious and effective solutions and to develop in-depth solutions using scientific methods. Teachers stated that problem-solving skills enable students to produce more conscious and effective solutions. For example,

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one teacher said, *"...students should produce conscious and effective solutions to the problems they encounter by using scientific methods." [A].* Another teacher emphasized that using scientific knowledge increases the quality of producing solutions: *"...using scientific knowledge in the problem-solving process increases the quality of producing solutions." [B].* Teachers stated that research literacy and socio-scientific reasoning support the generation of more in-depth and conscious solutions in the problem-solving process. For example, one teacher stated that *"...students should produce comprehensive solutions by combining scientific knowledge and ethical values." [C].* Another teacher stated that scientific methods enable students to make more in-depth analyses: *"...scientific methods enable students to make more in-depth analyses and produce effective solutions to problems." [D].*

Discussion

In this study, the correlation between research literacy, socio-scientific reasoning, and problem-solving skills was analyzed, along with the predictive effects of these skills on problem-solving, using both quantitative and qualitative methods. The findings revealed significant and positive correlations among these three skills. These results align closely with existing studies in the literature, emphasizing their interdependent nature, particularly within the framework of 21st-century skills (Bentz et al., 2024; Dhakal, 2022; Evans, 2017; Gutman & Genser, 2017; Izumi-Taylor, 2023; Ngu et al., 2024; Romine et al., 2020; Waring, 2017). Quantitative analyses indicated a significant correlation between research literacy and socio-scientific reasoning. Moreover, both research literacy and socio-scientific reasoning were found to be significant predictors of problem-solving skills. These findings align with previous studies suggesting that students' ability to critically access and evaluate scientific knowledge enhances their capacity to draw logical inferences within social and ethical contexts (Chang et al., 2018; Evans et al., 2017; Varlik, 2024). However, while most existing studies examine these correlations from a descriptive and confirmatory perspective, in-depth analyses of causal relationships remain limited. Qualitative findings further reinforce this correlation. Science teachers emphasized that research literacy serves as the foundational building block for socio-scientific reasoning skills, a perspective consistent with prior research (Filho et al., 2024; Shank et al., 2018). These findings underscore the need for a holistic approach to the simultaneous development of these two competencies in educational settings. One of the key insights from this study is the positive effect of research literacy on problem-solving skills. The high standardized β coefficient observed in the quantitative analyses highlights the strength of this relationship. Research literacy enhances students' ability to generate solutions based on scientific knowledge, thereby fostering the development of creative and effective strategies in the problem-solving process (Beaudry & Miller, 2016; Dhakal, 2022; Heikkilä & Eriksen, 2023). This finding aligns with studies that position research literacy as a central pillar of education (Adams, 2024; Johnson, 2024; McGregor, 2018; Ong et al., 2024). Despite these findings, existing studies often fail to examine in detail which variables amplify or diminish these interactions. This suggests that the impact of research literacy may vary across different learning environments or student demographics. Furthermore, there is limited evidence regarding the contribution of research literacy to problem-solving in interdisciplinary contexts, particularly within the social sciences. This raises the question of whether research literacy exerts a uniform effect across diverse academic domains. One of the most striking findings of this study is the impact of socio-scientific reasoning on problem-solving skills. The very high correlation coefficient and standardized β coefficient indicate that socio-scientific reasoning is a strong determinant of problem-solving ability. Teachers' perspectives corroborate this finding, as they assert that socio-scientific reasoning enhances students' capacity to evaluate complex problems within social and ethical contexts. This conclusion is consistent with prior research (Allchin et al., 2024; Attri, 2018; Filho et al., 2024; Langner & Graulich, 2024; Sadler, 2021; Ventistas et al., 2024; Zheng, 2023). Moreover, this finding suggests that students should not only develop technical competencies but also cultivate ethical and social responsibility (Abell, 2007; Uyanık, 2024). However, from a critical standpoint, it is essential to recognize that correlation does not imply causation. For instance, does socio-scientific reasoning directly enhance problem-solving skills, or is it possible that individuals with advanced problem-solving abilities naturally excel in socio-scientific reasoning? The directionality of this relationship remains a point of debate in the literature. While previous studies indicate that socio-scientific reasoning contributes to students' problem-solving processes, they do not sufficiently explore whether this correlation is independent of prior academic background or cognitive abilities. Incorporating variables such as individual differences and prior academic achievement into future research methodologies could yield more precise insights into the nature of this relationship. Science teachers in this study conceptualized research literacy, socio-scientific reasoning, and problem-solving skills as interdependent and mutually reinforcing competencies. Research literacy is defined as students' ability to understand scientific processes, adopt a critical perspective, and apply scientific methods

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(Johnson, 2024; Sambey, 2016). Socio-scientific reasoning entails the capacity to assess scientific knowledge within social and ethical contexts (Knain, 2015), while problem-solving skills encompass the ability to identify (Zheng, 2023), analyze (Hiremath, 2024), and generate creative and strategic solutions (Musa, 2024). The synergy among these skills enables students to apply scientific knowledge effectively to real-life challenges (Akpan et al., 2023; Seher Budak & Defne Ceyhan, 2023). Research literacy fosters the ability to access and critically evaluate scientific information (Menard, 2003), while socio-scientific reasoning facilitates the application of this knowledge to social issues and ethical dilemmas (Abell, 2007; Uyanık, 2024). Problem-solving skills integrate these competencies, enhancing students' capacity to devise innovative and practical solutions (Beghetto, 2018; Ngu et al., 2024). Teachers emphasized that these three skills are crucial for students' cognitive development and academic success. This perspective is supported by prior research (Adams, 2024; Finnegan, 2024; Gillies, 2024; Ong et al., 2024). However, an ongoing challenge is how to integrate these competencies more effectively within educational curricula. Although existing studies highlight the necessity of developing these skills in tandem, educational systems often treat research literacy and socio-scientific reasoning as separate domains. Consequently, students typically acquire these skills in a theoretical rather than applied context. This suggests that traditional pedagogical approaches may be insufficient in fostering these competencies and that problem-centered or interdisciplinary strategies may be more effective. Furthermore, compared to existing literature, there is a need for further research on how these correlations respond to contextual variables, individual differences, and interdisciplinary considerations. Specifically, the nature and mechanism of socio-scientific reasoning's impact on problem-solving skills warrant more in-depth investigation. Additionally, practical recommendations should be developed for effectively integrating these skills into educational and training programs.

Conclusions and Implications

This study examined the levels of research literacy, socio-scientific reasoning, and problem-solving skills, along with their intercorrelations and effects on problem-solving abilities. The findings indicated that all three skills were highly developed among participants and demonstrated significant positive correlations with each other. Regression analyses further revealed that both research literacy and socio-scientific reasoning had significant positive impacts on problem-solving skills, with socio-scientific reasoning showing a particularly strong effect. These results highlight the critical role of these three skills in enhancing students' scientific and analytical thinking capacities, as they mutually reinforce one another. The study underscores the necessity of considering research literacy, socio-scientific reasoning, and problem-solving skills as an integrated whole in students' cognitive development. Not only do these skills foster scientific knowledge and critical thinking on an individual level, but they also facilitate the application of scientific understanding within social and ethical contexts. Socio-scientific reasoning, in particular, serves as a vital bridge between comprehending and applying scientific knowledge, while problem-solving skills empower students to devise creative and effective solutions to real-world challenges. These findings support the theoretical significance of an integrated skills approach in education. Based on these insights, adopting a holistic strategy for developing these three skills is essential for shaping educational policies and teaching methodologies.

In science curricula, greater emphasis should be placed on activities that enhance research literacy, discussions centered on socio-scientific issues, and creative problem-solving tasks. Teachers should be adequately trained and equipped with the necessary expertise to guide students in cultivating these competencies. Additionally, implementing innovative pedagogical approaches such as interdisciplinary activities and problem-based learning is expected to facilitate meaningful connections between these skills. In this context, it is imperative to incorporate research literacy, socio-scientific reasoning, and problem-solving skills into a cohesive framework within curriculum design and teacher education programs. This study has demonstrated the crucial role of these competencies in both individual and societal contexts, offering both theoretical insights and practical recommendations for fostering their development.

Recommendations

The findings of this study provide important insights for the design of educational programs. The strong intercorrelation between research literacy, socio-scientific reasoning, and problem-solving skills underscores the need for an integrated instructional approach. To equip students with the ability to navigate both scientific and societal challenges, educational programs should be restructured to cultivate these skills cohesively. Teacher training should be enhanced with targeted content on the pedagogy and assessment of these competencies. Furthermore,

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interdisciplinary approaches and student-centered learning strategies should be prioritized, with an emphasis on real-world problem-solving activities. The integration of technology and digital tools into teaching and learning processes should be strengthened, and assessment methods should be diversified to include process-oriented and performance-based evaluations. At the policy level, national strategies should be developed to foster these essential skills, ensuring that schools provide supportive and resource-rich learning environments.

Limitations

In this study, the combination of quantitative and qualitative data increased the depth of the findings. However, the fact that the study was limited to science teachers is a limitation in terms of generalizability. Conducting similar studies with teachers and students from different branches in future studies may expand the scope of the findings. In addition, the development processes and long-term effects of these skills can be examined in more detail by using longitudinal designs.

References

Abell, S. K. (2007). *Handbook of research on science education*. Routledge.
Adams, J. D. (2024). *Teacher learning and informal science education expansivising affordances for diverse science learners*. Peter Lang.
Adams, K. A., & McGuire, E. K. (2023). *Research methods, statistics, and applications*. Sage.
Akpan, B., Cavas, B., & Kennedy, T. (Eds.). (2023). *Contemporary issues in science and technology education*. Springer.
Allchin, D., Bergstrom, C. T., & Osborne, J. (2024). Transforming science education in an age of misinformation. *Journal of College Science Teaching, 53*(1), 40–43. https://doi.org/10.1080/0047231X.2023.2292409
Attri, R. K. (2018). *Accelerating complex problem-solving skills: Problem-centered training design methods*. Speed to Proficiency Research.
Beaudry, J. S., & Miller, L. (2016). *Research literacy: A primer for understanding and using research*. Guilford Publications.
Beghetto, R. A. (2018). *What if? Building students' problem-solving skills through complex challenges*. ASCD.
Bentz, A., Krasowski, J., Standl, B., & Wiepcke, C. (2024). Empowering K–12 pupils: Fostering problem-solving skills through sustainable entrepreneurship and computational thinking. *Journal of the International Council for Small Business*, 1–12. https://doi.org/10.1080/26437015.2024.2403030
Bettman, J. R. (1979). *An information processing theory of consumer choice*. Addison-Wesley Publishing.
Blair, G., Coppock, A., & Humphreys, M. (2023). *Research design in the social sciences: Declaration, diagnosis, and redesign*. Princeton University Press.
Chang, H. Y., Hsu, Y. S., Wu, H. K., & Tsai, C. C. (2018). Students' development of socio-scientific reasoning in a mobile augmented reality learning environment. *International Journal of Science Education, 40*(12), 1410–1431. https://doi.org/10.1080/09500693.2018.1480075
Chen, D. G., & Yung, Y. F. (2023). *Structural equation modeling using R/SAS: A step-by-step approach with real data analysis*. CRC Press.
Cipresso, P., & Immekus, J. C. (2022). *Statistical guidelines: New developments in statistical methods and psychometric tools*. Frontiers Research Topics.
Crano, W. D., Brewer, M. B., & Lac, A. (2023). *Principles and methods of social research*. Routledge.
Creamer, E. G. (2025). *Visual displays in qualitative and mixed method research: A comprehensive guide*. Taylor & Francis.
Creswell, J. W., & Guetterman, T. C. (2019). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Pearson.
Çıldır, S., & Acarlı, D. S. (2024). Perception scale of preservice science teachers' socio-scientific reasoning skills. *Journal of Baltic Science Education, 23*(6), 1152–1163. https://doi.org/10.33225/jbse/24.23.1152
Davis, S. H. (2008). *Research and practice in education: The search for common ground*. R&L Education.
Denscombe, M. (2020). *Research proposals: A practical guide*. McGraw Hill.
Denzin, N. K., & Lincoln, Y. S. (Eds.). (2018). *The SAGE handbook of qualitative research*. Sage.
Dhakal, K. M. (2022). Collaborating with clinical pastoral educators to teach a research literacy curriculum. *Journal of Hospital Librarianship, 22*(1), 1–7. https://doi.org/10.1080/15323269.2021.2019511
Evans, C. (2017). Early career teachers' research literacy: What does it look like and what elements support its development in practice? *Research Papers in Education, 32*(4), 540–551. https://doi.org/10.1080/02671522.2017.1324013
Evans, C., Waring, M., & Christodoulou, A. (2017). Building teachers' research literacy: Integrating practice and research. *Research Papers in Education, 32*(4), 403–423. https://doi.org/10.1080/02671522.2017.1322357
Fetters, M. D. (2020). *The mixed methods research workbook: Activities for designing, implementing, and publishing projects*. Sage.
Fındık, L. Y. (2024). *Exploring adult education through learning theory*. IGI Global.
Filho, W. L., Salvia, A. L., & Vasconcelos, C. R. P. (2024). *An agenda for sustainable development research*. Springer.
Finnegan, C. (2024). *Science education in focus: Exploring science teacher attitudes and classroom practices through the lens of science capital*. Dublin City University.
Flick, U. (Ed.). (2022). *The SAGE handbook of qualitative research design*. Sage.
Frey, B. B. (Ed.). (2018). *The SAGE encyclopedia of educational research, measurement, and evaluation*. Sage.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Garg, G. (2023). *Understanding child psychology for better upbringing*. Gaurav Garg.

Gillies, R. M. (2024). *Inquiry-based science education*. CRC Press.

Gunbayi, I. (2023). Data analysis in qualitative research. *Journal of Action Qualitative & Mixed Methods Research, 2*(2), 1–11. https://doi.org/10.5281/zenodo.776320

Gunbayi, I. (2024). Rigor in qualitative research. *Journal of Action Qualitative & Mixed Methods Research, 3*(2), 1–7. https://doi.org/10.5281/zenodo.13256320

Heikkilä, M., & Eriksen, A. (2023). Polyphonic agency as precondition for teachers' research literacy. *Educational Philosophy and Theory, 56*(1), 63–73. https://doi.org/10.1080/00131857.2023.2224560

Herranen, J., & Aksela, M. (2019). Student-question-based inquiry in science education. *Studies in Science Education, 55*(1), 1–36. https://doi.org/10.1080/03057267.2019.1658059

Hiebert, J., Cai, J., Hwang, S., Morris, A. K., & Hohensee, C. (2023). *Doing research: A new researcher's guide*. Springer.

Hiremath, M. (2024). *Master the art of problem-solving skills: Enhance decision-making techniques, strengthen resilience, conquer challenges, and achieve lasting success*. Notion Press.

Izumi-Taylor, S. (2023). The mimamoru approach: Supporting young children's problem-solving skills in Japan. *Childhood Education, 99*(6), 30–35. https://doi.org/10.1080/00094056.2023.2282889

Johnson, L. R. (2024). *Finishing first in science education: What will it take?* Rowman & Littlefield Publishers.

Johnson, R. B., & Christensen, L. (2020). *Educational research: Quantitative, qualitative, and mixed approaches.* Sage.

Karukstis, K. K., & Elgren, T. E. (2007). *Developing and sustaining a research-supportive curriculum: A compendium of successful practices.* Council on Undergraduate Research.

Kmetz, J. L. (2018). *The information processing theory of organization: Managing technology accession in complex systems.* Taylor & Francis.

Knain, E. (2015). *Scientific literacy for participation: A systemic functional approach to analysis of school science discourses.* Sense Publishers.

Langner, A., & Graulich, N. (2024). From sight to insight – Reflection processes in an eye-gaze-augmented retrospective. *International Journal of Science Education, 1–24.* https://doi.org/10.1080/09500693.2024.2430804

McGregor, S. L. T. (2018). *Understanding and evaluating research: A critical guide.* Sage.

Menard, M. B. (2003). *Making sense of research: A guide to research literacy for complementary practitioners.* Curties-Overzet Publications.

Mertens, D. M. (2023). *Mixed methods research.* Bloomsbury Academic.

Muchlas Abrori, F., Lavicza, Z., & Anđić, B. (2023). Enhancing socio-scientific reasoning of elementary school students through educational comics: A comprehensive exploration across diverse domains of knowledge. *Education 3-13, 1–22.* https://doi.org/10.1080/03004279.2023.2266457

Musa, A. (2024). *How to teach problem-solving skills in the digital era.* E-kitap.

Newsom, J. T. (2024). *Longitudinal structural equation modeling: A comprehensive introduction*. Taylor & Francis.

Ngu, B. H., Phan, H. P., Usop, H., & Anding, P. N. (2024). Enhancing problem-solving skills for word problems: Impact of diagram and learner expertise. *The Journal of Experimental Education, 1–18.* https://doi.org/10.1080/00220973.2024.2394956

Okoko, J. M., Tunison, S., & Walker, K. D. (2023). *Varieties of qualitative research methods: Selected contextual perspectives.* Springer.

Ong, Y. S., Tan, T. T. M., & Lee, Y. J. (Eds.). (2024). *A diversity of pathways through science education.* Springer.

Orhan, U., & Genç, M. (2024). Socio-scientific reasoning of science, social studies and primary teachers. *Research in Science & Technological Education, 1–18.* https://doi.org/10.1080/02635143.2024.2338808

Petermann, B. (2013). *Foundations of gestalt theory.* Taylor & Francis.

Phiri, C. (2024). *Quantitative research made easy: A step-by-step guide for postgraduate students.* Amazon.

Powel, W. A. (2021). *Socioscientific issues-based instruction for scientific literacy development.* IGI Global.

Rizvi, R. H. (2024). *Unlocking problem-solving skills.* R. H. Rizvi.

Romine, W. L., Sadler, T. D., Dauer, J. M., & Kinslow, A. (2020). Measurement of socio-scientific reasoning (SSR) and exploration of SSR as a progression of competencies. *International Journal of Science Education, 42*(18), 2981–3002. https://doi.org/10.1080/09500693.2020.1849853

Sadler, T. D. (Ed.). (2021). *Socio-scientific issues in the classroom: Teaching, learning and research.* Springer.

Sambey, C. A. G. E. (2016). *Academic and research literacy practices of final year teacher trainees in Luanda, Angola.* Cambridge.

Savin-Baden, M., & Major, C. H. (2022). *Qualitative research: The essential guide to theory and practice.* Taylor & Francis.

Seher Budak, U., & Defne Ceyhan, G. (2023). Research trends on systems thinking approach in science education. *International Journal of Science Education, 46*(5), 485–502. https://doi.org/10.1080/09500693.2023.2245106

Shah, S. (2019). *Early childhood development in humanitarian crises: South Sudanese refugees in Uganda.* Taylor & Francis.

Shank, G., & Brown, L. (2007). *Exploring educational research literacy.* Taylor & Francis.

Shank, G., Pringle, J., & Brown, L. (2018). *Understanding education research: A guide to critical reading.* Taylor & Francis.

Shattuck, K. (2020). Distance education research literacy begins with the literature. *American Journal of Distance Education, 34*(3), 179. https://doi.org/10.1080/08923647.2020.1802965

Sinha, S. (2020). *Problem-solving techniques: Problem-solving skills simplified.* Independently Published.

Uyanık, G. (Ed.). (2024). *Eğitim & Bilim 2024: Fen eğitiminde geleneksel ve modern uygulamalar [Education & Science 2024: Traditional and modern practices in science education].* Efe Akademi Yayınları.

Varlik, S. (2024). Critical and creative thinking in science teachers: The moderating role of epistemology. *Journal of Baltic Science Education, 23*(5), 964–978. https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Ventistas, G., Ventista, O. M., & Tsani, P. (2024). The impact of realistic mathematics education on secondary school students' problem-solving skills: A comparative evaluation study. *Research in Mathematics Education, 1–25*. https://doi.org/10.1080/14794802.2024.2306633

Wahyuni, S. (2024). *Qualitative research method: Theory and practice.* Penerbit Salemba Empat.

Wallace, B., Maker, J., Cave, D., & Chandler, S. (2013). *Thinking skills and problem-solving: An inclusive approach – A practical guide for teachers in primary schools.* Taylor & Francis.

Waring, M. (2017). Research literacy: Contextual affordances and the ongoing quest for sustainability and research quality. *Research Papers in Education, 32*(4), 538–539. https://doi.org/10.1080/02671522.2017.1322354

Wertheimer, M., & King, D. B. (2005). *Max Wertheimer and gestalt theory.* Transaction Publishers.

Yaman, S., & Dede, Y. (2008). Yetişkinler için problem çözme becerileri ölçeği [Problem solving skills scale for adults]. *Journal of Educational Sciences & Practices, 7*(14), 251-269.

Yıldız, D., Kılıç, M. Y., Gülmez, D., & Yavuz, M. (2019). Öğretmenlerin araştırma okuryazarlığı becerileri: Ölçek geliştirme çalışması [Teachers' research literacy skills: A scale development study]. *Turkish Journal of Educational Studies, 6*(1), 45-65. https://doi.org/10.33907/turkjes.500780

Zheng, M. (2023). *How to improve your problem-solving skills: Smart strategies for making better decisions.* Amazon.

Zou, P. X. W., & Xu, X. (2023). *Research methodology and strategy.* Wiley.

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„SCIENCE AND TECHNOLOGY EDUCATION: EXPECTATIONS AND EXPERIENCES“

Dear Colleagues,

On behalf of the organizing committee, we are delighted to welcome you to Šiauliai, Lithuania, for the VI International Baltic Symposium on Science and Technology Education, BalticSTE 2025. The Symposium will be held in **Šiauliai (Lithuania)** in **June 2025** during days **16-19**.

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Website: https://www.balticste.com/

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Kind regards,
Symposium committee

Baltic STE

Šiauliai, Lithuania

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